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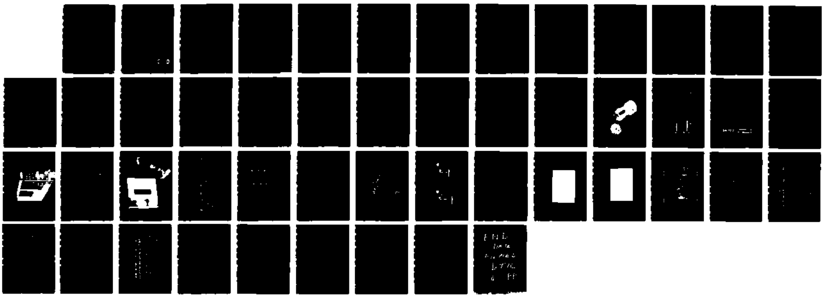

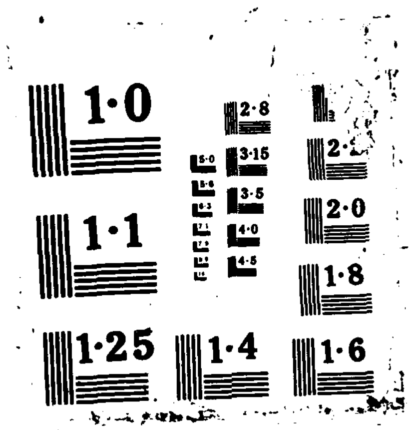
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FIRE PROTECTION SYSTEMS UTILIZED
IN
UNITED STATES ARMY AMMUNITION PLANTS
(ULTRA HIGH SPEED DELUGE SYSTEMS)

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SAFETY OFFICE

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The ~~paper~~ discusses pre-primed ultra-high-speed deluge systems used to protect personnel, process equipment, and buildings from the fire and thermal hazards presented by munitions loading and maintenance operations such as weighting, pressing, pelletizing, propellant loading, melting, extrusion, mixing, blending, screening, sawing, granulation, drying, and pouring. It provides an understanding of what an ultra-high-speed deluge system is, how it functions, and its limitations; how the hazard is defined by means of a hazard analysis; the prevention of design, installation, and maintenance problems; the prevention false activations; how response time is defined and measured; and areas requiring additional effort.

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ULTRA HIGH-SPEED DELUGE SYSTEMS

1. Pre-primed, ultra high-speed deluge systems are used to protect personnel, process equipment, and buildings from the fire and thermal hazards presented by munition handling operations such as weighing, pressing, pelletizing, propellant loading, melting, extrusion, mixing, blending, screening, sawing, granulating, drying, and pouring. An ultra high-speed deluge system is designed to respond in milliseconds by detecting a flame or ignition source in its incipient stage and by applying large volumes of water. A pre-primed, ultra high-speed deluge system utilizes the following components:

- Flame detector (ultraviolet (UV) or infrared (IR)).

- Electronic controller (microprocessor).

- Valve (squib or solenoid operated).

- Pre-primed piping system with nozzles.

- Water supply.

2. When a flame detector senses the radiant energy of a flame or ignition source within its field of coverage, it will respond within milliseconds, sending a signal to the electronic controller. The controller, in turn, sends a signal to the valve to open. Opening of the valve permits supply line water pressure to be applied to the priming water already in the pipe between the valve and the nozzles, causing water to flow from the nozzles suppressing the fire. At the same time, signals are sent to operate alarms and shut down process equipment. Approximately 500 pre-primed, ultra high-speed deluge systems are used within the U.S. Army ammunition plant complex. We will discuss the components of an ultra high-speed deluge system in more detail later.

3. The ultra high-speed deluge system evolved from the conventional automatic sprinkler system. The conventional-type systems utilize closed heads with fusible links. It requires several minutes for the fusible links to melt and water to flow in the event of a fire. Next, came open head systems which were dependent upon heat actuated devices (HAD) to sense the fire and open a valve which permitted the water flow. Depending upon the HAD location, detection and water flow required ½ to 2 minutes. Finally, came the ultra high-speed deluge systems that use flame detectors (IR and UV), solid state electronic devices, explosively-actuated or solenoid-actuated valves, and the use of a pre-primed piping system and nozzles to provide adequate water patterns and densities.

4. The flame detector is an optical device that responds to the radiant energy that is given off by a flame. When a flame or ignition source occurs within the field of view of the detector, the resulting electromagnetic radiation travels toward the detector at the speed of light. The detector responds to the radiant energy in milliseconds, sending a fire signal to the electronic controller.

5. The UV fire detector (see figure 1) consists of a gas-filled cold cathode sensor tube that is mounted inside an explosion-proof housing. The sensor tube is designed to respond to a narrow band of radiation typically between 1,850 and

2,450 angstroms. Figure 2 illustrates the general relationship between solar radiation at the surface of the earth and the spectral response region of a typical gas-filled UV sensor. As you will note, the solar radiation spectrum extends approximately from 2,850 to 30,000 angstroms. Therefore, the sensor tube does not respond to solar radiation or normal ambient light.

6. Radiation is not emitted continuously, but is emitted in small bundles called photons. The energy of a photon is dependent on the wavelength of the radiation. When a protcn of radiation is absorbed into a metal such as the cathode (negative plate) of the UV tube, the energy of the proton is imparted to an electron within the metal, causing it to leave the surface of the metal and be drawn toward the anode (positive plate). The energy that the electron must have to leave the metal is called the work function of the metal. The sensitivity range of the radiation detector is dependent upon the work function of the metal used in the cathode.

7. The sensor tube is filled with an ionizable gas, such that when an electron is emitted from the cathode and is rapidly drawn to the anode, as shown in figure 3, it strikes a gas molecule with enough energy to cause electrons to be emitted from the gas molecule. These electrons strike other gas molecules releasing more electrons. The total number of electrons generated in this manner is typically several million times more than were emitted from the cathode.

8. The current can be stopped by reducing the applied voltage to the tube so that the emitted electron does not have sufficient energy to cause other electrons to be emitted when it collides with gas molecules.

9. In a typical UV detector, the current is allowed to flow for a very short period of time before the voltage is reduced and the current stopped. When the voltage is reapplied to the tube, it will again conduit if radiation is still present. The output of the sensor tube, therefore, is a series of voltage pulses the frequency of which is proportional to the intensity of the UV sensed by the detector. The closer a fire is to the detector, the higher the output frequency, the faster the response, and the smaller the flame size that is needed to actuate the system.

10. In the past, the circuitry in the controller that was used for counting the voltage pulses would amplify and store the pulses and then use the pulses to charge a capacitor. When the capacitor was charged to a pre-calibrated threshold voltage, the controller generated an output signal that energized the alarm relays and deluge systems.

11. The use of microprocessors (see figure 4) now makes it possible to count and process the digital pulses from the UV detectors. Pulses no longer need to be stored in capacitors, but can be individually counted, entered into the registers of the microprocessor, stored in memory, and manipulated like any type of data processing information. This allows the design of flexible UV fire detectors using programmable memories and switches to provide an infinite number of combinations. Thus, we now have a marriage of UV detection devices with state-of-the-art microprocessors. Since the UV detector requires no signal processing other than comparing the radiation level to a present threshold, a very fast response time is achieved.

12. Ultraviolet detectors are ideally suited for applications where rapidly developing fires can occur in open areas. Ultraviolet detectors can be used to monitor ammunition assembly lines and renovation operations involving open mixing operation or open areas that are stocked with energetic materials awaiting processing. These detectors are not typically affected by extremes of temperature or pressure, adverse weather conditions, high humidity, nor are they sensitive to solar radiation. They provide excellent area coverage and are suitable for use in the open. The UV detector is sensitive to welding arcs, lightning, gamma radiation, high electrostatic charges, and is easily obscured by contamination on the detector lens or in the atmosphere.

13. When properly applied, UV detectors can serve as excellent fire detectors in munitions manufacturing. Detection times as fast as 10 milliseconds can be achieved while effectively resisting false alarms. The majority of detectors used in the U.S. Army ammunition plant complex are UV detectors.

14. The IR detector is an extremely fast device that is capable of detection times as low as 5 milliseconds. In the past, IR detectors have been unsuitable for ultra high-speed deluge systems protecting munition operations because of the large number of false alarm stimuli found in the workplace. However, when properly applied in controlled surroundings, they can provide reliable and effective protection.

15. A typical high-speed IR detector (see figure 5) consists of an element such as cadmium selenide that is contained in a stainless steel housing. The resistance of the element changes when exposed to IR radiation. When it drops to a predetermined threshold, the controller responds. By using a narrow bandpass IR filter that is designed to minimize extraneous and ambient light sources, response is confined to the 0.75 to 0.85 micron range. This is the range that provides the fastest detector response. Figure 6 illustrates the general relationship between solar radiation at the surface of the earth and the spectral response range of a typical high-speed IR detector.

16. Like ultraviolet detectors, IR detectors have their advantages and limitations. Several advantages of IR units make them valuable in certain installations:

a. They do not respond to the strong UV radiation from electric arc welding and lightning.

b. X-ray and gamma radiation do not extend to the IR region, and neither single frequency nor multi-frequency IR units are affected by them.

c. Smoke and/or vapors do not significantly absorb radiation in the IR spectrum. This makes devices of this type particularly useful when heavy smoke concentrations may accompany a fire. However, care must be taken that IR absorbing dusts are not part of the hazard.

d. An IR detector can "see" through substantially more contamination on its viewing window than a UV detector.

e. They are able to see hot ember-like fires typical of oxygen depleted areas.

17. The IR spectrum is broad, and there are many sources of IR that radiate over the entire IR band. Typical are hot manifolds, boilers, processing vessels, engines, and the sun itself. With some types of IR detectors, the background radiation from a heat source can actually mask the presence of a fire and result in failure to respond. While simple high-speed IR systems have been available for several years, modern sensor and filter developments, coupled with state-of-the-art electronics, have resulted in systems tailored for the munitions industry. These systems are more selective within the electromagnetic spectrum, fast in response, and extremely flexible in application to supression systems. However, high-speed IR sensors still must be carefully isolated from possible false alarm sources. Such sources include the sun and other blackbody radiation sources, high intensity light, flashbulbs, and florescent and incandescent lighting. Typical applications for these high-speed IR detectors are characterized by strictly controlled, dark environments where a flash fire could originate. Conveyor belts passing through large covered ducts and closed explosive and propellant mixers are examples of the controlled environment necessary for proper application.

18. Typically, these systems are recommended to be used in combination with the appropriate UV systems, combining the advantages of UV for space protection with IR for enclosed areas. When dealing with an entire fire detection system that utilizes one or more than one type of detector, a detonator module greatly expands the flexibility and capability for the system. An individual detonator module can accept multiple input from UV and IR controllers, other detonator modules, manual alarm stations, heat sensors, smoke detectors, pressure sensors, or any contact closure device. In the event of a fire, any of these devices will cause the internal fire circuitry of the module to activate the detonator circuit, sound alarms, shut down process equipment, and identify the zone that detected the fire. When properly used, some detonator modules can add only a few milliseconds to the total system response time.

19. The detectors usually contains a test source within the enclosure. When a test signal is applied to the source, IR or UV radiation is generated for testing the detector. This test also checks the sensor and its wiring without resulting in a false alarm. The detectors are usually connected to a controller that supplies power to the detectors and acts as a signal processor and output device. Reliable operation of the system is ensured by the ability of the detonator module to continuously monitor the input circuits and the detonator output circuits, to supervise the solenoid valve and the wiring to the solenoid valve or squib, as well as to perform a self-test procedure to allow verification of other critical circuits.

20. We are now seeing dual IR-UV detectors and dual IR-IR detectors which will look at two separate bands of IR and/or UV radiation becoming available for munitions application. There will also be cross-zoning and matrixing of detectors. This requires a combination of detectors to see a fire or flame before the controller activates the deluge system.

21. There are two primary types of ultra high-speed fire suppression systems presently used in the U.S. Army ammunition plant complex. They are the squib-actuated valve and the solenoid-actuated valve.

22. The basic components of the squib-operated system are one or more IR or UV flame detectors, controller, detonator module, a water control (deluge valve) activated explosively by a squib, a water-primed piping system in which the water is retained by the use of rupture disk or nozzle cap, deluge discharge nozzles, and supervisory test devices (see figures 7 and 8). When the detection system senses the presence of radiant energy of an intensity and wavelength exceeding the detector's threshold, it sends an amplified electrical signal to the controller and detonator module which detonates the squib/primer in the control valve. The primer fires releasing a latch allowing the water supply line pressure to open the valve, thus, increasing the priming water pressure in the piping to the nozzle cap or rupture disk. The line pressure blows off the nozzle caps or bursts the rupture disk allowing water flow to the hazard. If required, dust caps can be utilized with nozzles controlled by ruptured disk assembly.

a. The squib operating valves range in size from 2 to 6 inches (5 to 15 cm). When the 2- or 2½-inch (5 or 6 cm) valve is prepared for service, the valve is placed in the set position. The latch, which is prevented from swinging by a shear pin, holds the plunger and shaft assembly in the set position, where the plunger o-ring creates a seal to that the supply pressure does not enter the system piping (see figure 9). This also prevents the accidental release of the latch due to water hammer and normal piping and building vibration. An electrical signal from the control panel fires the dual primers in the primer holder. The force exerted by only one of the primers is enough to pivot the latch and break the shear pin. The latch swings into the tripped position and the supply pressure lifts the plunger and shaft assembly out of the seated position. The primed piping system is very rapidly pressurized by the supply water, and the water is discharged out of the nozzles after the disc or cap ruptures. The 2- and 2½ inch (5 or 6 cm) valves can be installed either vertically or horizontally, but vertical is preferable. The operating principle of the 4- and 6-inch (5 to 15 cm) valves is similar.

b. Explosive squib wiring can be supervised by sending a low voltage current through the squib wiring and the squib. Preventative maintenance is very costly. Each time the system is tripped, the two squibs, the latch pin, the squib holder, and the rupture disks must be replaced. Valves may be located in nonhazardous areas which usually require longer pipe runs. If located in the hazardous area, the area must be cleared of explosives prior to replacement of the squibs. The valves are approved for electrical Class II (dust) locations. Squibs could explode while being installed; therefore, a face shield must be worn when this work is performed. Line water pressure is maintained up to the valve.

c. The following safety guidelines should be observed by personnel handling and installing primers and squibs used in deluge valves:

(1) Store with compatible energetic materials. Primers are usually class 1.4, compatability group B.

(2) Shut off power to control panel.

(3) Do not untwist the ends of primer lead wires.

(4) Always wear goggles.

(5) Only wear cotton clothing when handling primers, in order to help prevent a discharge of static electricity.

(6) Do not smoke while handling primers.

(7) Do not expose primers to flame or any source of heat.

(8) The area around a valve in which primers are to be installed must be kept free of potentially explosive vapors and materials until the primers are sealed within the valve's explosion-proof enclosures; i.e., acess and junction boxes.

(9) Do not place the ends of the primer leads in contact with any source of electrical potential (such as a battery) or stray electrical current.

(10) Do not use an ohm meter or other current-producing device to check the electrical continuity of a primer.

(11) Do not permit anyone to work on a valve's control unit (Primer Release Detonating Panel) while installing primers in the valve. Place a sign on the control unit which indicates "DETONATING SYSTEM BEING SERVICED - DO NOT TOUCH PANEL."

23. The basic components of the solonoid-operated system are one or more IR or UV flame detectors, controller, pilot line solenoid, pilot control valve and nozzle, and supervisory test devices (see figure 10). In this system, the nozzle and associated valve is a pilot line-operated nozzle (relief) valve that is kept closed against the supply (fire) line pressure by the water pressure in the pilot line. This pilot line is normally connected to the water main as a source of pressure. The differential on the valve activating surface area (pilot line versus main water line pressure) maintains the nozzle valve in the closed position. The detector system may utilize IR or UV detectors. These detectors, upon responding to a fire, send an amplified signal to the controller, which, in turn, sends a signal to the pilot line solenoid-operated relief valve, causing it to open. This drops the pilot line pressure allowing the pilot control nozzle valves to open and main line water to flow (see figures 11 and 12). The pilot line is small enough to prevent the pilot pressure from being maintained with the relief valve in the open position. When pilot pressure is restored, the poppet reseats, even against fire main pressure. A solenoid valve consists of a two-piece body threaded together and sealed with an o-ring. The upper body has ½-inch (.635 cm) NPT male connection for installation and standard pipeline fittings and 1/4-inch (.318 cm) NPT female connection from the pilot line. The poppet has a teflon face which seats against the orifice located in the lower body half of the valve. The lower body is interchangeable to accommodate various types of

discharge devices. Male adapters are often used where there is a need for flange mount such as to the cover of a melt kettle or mixer. The female adapter is most often used with the nozzles. The solenoids are equipped with an enclosure which is designed to meet electrical class I (vapors) and class II (dusts) locations. If required, dust caps can be utilized with nozzles controlled by solenoid valves.

24. The solenoid valve can be reset at the control valve by one person. Blow-off caps or rupture disks are not required. The system is easy and relatively inexpensive to maintain and test. The flow of water is easy to start or stop. Water pressure is maintained up to the nozzle. Pilot line solenoid valves should be located within 8 feet (2.5 meters) of the nozzle. Normally, it is recommended that a maximum of 20 nozzles be used per system. Although one solenoid can control several nozzle valves, faster response times can be achieved when each nozzle valve has a separate solenoid. This valve is designed to perform properly when mounted in any position. However, for optimum life and performance, the solenoid should be mounted vertically to reduce the possibility of foreign matter accumulating in the core tube area.

25. A third type of ultra high-speed deluge system uses the explosive rupture disc (see figure 13). It has seen only limited use in the ammunition plant complex. It consists of pre-primed piping with explosive rupture discs placed behind each nozzle. When a fire is detected, the squibs are fired, rupturing the disc, providing water at a very fast rate. This system can be preprimed at a much higher pressure than the squib valve. See figure 14 for typical layout. This type of system has been used on ammunition peculiar equipment.

26. The justification for ultra high-speed deluge systems in an explosive facility would seem obvious, but there has been some debate on if and why this type of system is really necessary; the subject does deserve some discussion. The system must be designed to meet one or more of the following criteria: total suppression, prevention of propagation, prevention of injury, or protection of equipment or production down time. Ultra high-speed suppression has proven effective in prevention of propagation. For instance, during an explosive loading operation, the projectile being loaded initiated and the deluge system was able to prevent propagation of the main explosive hopper. In cases of personal protection, there have been many cases where operators have been doused by water and serious burns were prevented. Total extinguishment has been accomplished many times in past incidents. Depending on the cost of the equipment, even if it is a remote operation, savings can be substantial if the fire is extinguished or not allowed to propagate.

27. The operations in an explosive facility are also as varied as the products and the system should be customized and geared towards the operation. The types of operations commonly seen in explosive facilities are weighing, pressing, pellitizing, propellant loading, melting, extrusion, mixing, blending, screening, sawing, granulating, drying, pouring, and machining. Each presents its own specific hazard, and attention should be given to areas of ignition such as pinch points, friction points, and areas where there is an operator working. The fire detectors and nozzles should be put as close to the hazard as possible. In many cases, use dedicated nozzles to key-on specific problem areas, such as mixing

bins, machining processes, extruder dies, etc. As mentioned before, determine what is required of your system. Is it to stop propagation, protect personnel, or protect machinery? With this in mind, one can design a system that will effectively meet the needs. Each operation requires special consideration. For instance, during weighing, often with dry material, transfer and pouring of material can create dust and ignition. This is a good application for UV detection and high-speed water spray. In the case of pressing and pellitizing, usually the goal here would be to prevent propagation. During the pressing and pellitizing operation, there is a good chance of explosion or ignition, and the best bet would be to stop propagation to the bulk propellant or explosives. With propellant production, the transition of material from one vessel to another is a potential hazard, and it is a good idea to have UV detection here and directed water spray. In the process of melting, usually these are closed melt kettles using steam for heat and often in this case, IR detection with nozzles directed into the kettle is a common configuration. With extrusion, the most likely point of ignition is where the material leaves the die. An ultra high-speed deluge system will not stop a detonation of high explosives, but it can prevent propagation to adjacent energetic materials.

28. The United States Department of Defense Ammunition and Explosives Safety Standards (DOD 6055.9) states that where exposed thermally energetic materials are handled that have a high probability of ignition and a large thermal output as indicated by a hazard analysis they must be protected with an ultra high-speed deluge system. The system must suppress potential fires in their incipient state. Other publications such as AMCR 385-100 (U.S. Army Materiel Command Safety Manual), Navy Sea System Command OP 5 (Ammunition and Explosives Ashore), DOD 4145.26M (Contractor's Safety Manual), Military Handbook 1008 (Fire Protection for Facilities Engineering, Design, and Construction), and the National Fire Codes also provide guidance on ultra high-speed deluge systems.

29. The hazard to be protected must be accurately defined. The following factors should be considered:

- Quantity of exposed material.
- Initiation sensitivity.
- Heat output.
- Rate of burning.
- Potential ignition and initiation sources.
- Personnel exposure (including protective clothing).
- Frequency of operations.
- Munitions configuration.
- Process equipment and layout.
- Building design and construction.

30. A hazard analysis should be prepared defining the hazard in terms of hazard exposure, hazard severity, and hazard probability. The factors listed above should be considered. This could be either qualitative or quantitative. The MIL-STD 882 (System Safety Program Requirements) and other publications provide guidance on the preparation of hazard analysis. A potential fire and/or thermal hazard whose level of risk is unacceptable (as determined by the DOD component) should be mitigated by an ultra high-speed deluge system. Once the hazard has been accurately defined, the system can be properly designed.

31. With all of the exotic chemical fire suppressants available today, one might wonder why water is used for energetic materials, such as, propellants, explosives, and pyrotechnics. Most all explosives, propellants, and pyrotechnic mixes contain the necessary oxygen for the burning process. Most energetic materials are a combination of a fuel and an oxidizer. The oxidizers provide the oxygen required for burning. Some examples of oxidizers are the nitrate and chlorate families; i.e., potassium nitrate, potassium perchlorate, barium nitrate, potassium chlorate, ammonium nitrate, etc. Because of these oxygen-yielding substances, it is impossible to stop the propellant fire by suppressing the oxygen supply. Why water? Cooling is the principal factor because it prevents feedback of sufficient heat energy to maintain combustion. It is, of course, desirable to get the water to the actual burning surface. However, it is not enough to just wet the surface, as the fire will burrow into the mixture and continue to burn, being shielded from the water by an outer layer of water soaked material. This makes it highly desirable to be able to apply the water rapidly before burrowing can occur. Another factor which makes rapid operation essential is that water must reach the burning surface before the pressure of combustion gases is sufficiently high to prevent water from reaching the source of the fire. This requires that the system operate in a matter of milliseconds. In some cases, especially with large bulk quantities of explosives, it may be necessary to flood the container from the bottom and the top or possibly add a wetting agent to the water in the deluge system to allow penetration of the explosive.

32. The water density required will depend upon the type, quantity, and configuration of energetic material involved, process layout, and whether the goal is extinguishment, prevention of propagation, prevention of injury, or a combination of these. A commonly used density for preventing propagation and structural damage is 0.5 GPM/sq ft (200 liters/sq meter). The protection of personnel and process equipment as well as the extinguishment of pyrotechnic fires requires significantly higher density rates. These may be as high 3.0 GPM/sq ft (120 liters/sq meter) for area coverage or 50 GMP/nozzle (190 liters' per minute) for point of operation coverage. Tests have shown that fires involving some pyrotechnic materials being mixed require a water flow of 200 GPM (750 liters/minute) or more to extinguish.

33. An estimate of the maximum flow rate and pressure required by the deluge system should be made to determine water supply requirements. The capabilities of the existing water supply and distribution system to meet these requirements should be evaluated. A minimum static pressure of 45 to 50 pounds per square inch (3 atmospheres) is usually needed at the building. If the required flow rate and pressure is not available, arrangements must be made to provide it. The water pressure required for proper functioning of an ultra high-speed deluge system must be available instantaneously, usually from an elevated tank or

pressure tank. The instantaneous flow cannot be produced by starting a fire pump or jockey pump; however, a fire pump can be used to provide the required flow and pressure after the system has started to operate. Response time is directly related to water pressure -- the higher the static pressure the faster the response time. For most applications, the water supply should have a duration of at least 15 minutes. Water supply requirements for other deluge and sprinkler systems must also be considered. Since fires involving munitions are not normally fought, no allowance is required for fire department hose lines. However, the need for hose lines to protect nearby buildings from fires involving class 1.3 and 1.4 material and during cleanup should be considered.

34. System response time is a controversial issue that is often discussed but seldom settled. Response time criteria should be realistic and defined in a manner that will permit meaningful testing of the completed installation to ensure the performance criteria was met. There has been no common agreement on the definition of deluge system response time. This has caused confusion and prevented the development of a performance-type specification. This precludes the effective evaluation of ultra high-speed deluge systems.

35. In order to more precisely define response time requirements, it is necessry to understand the interrelation between development of an incident and deluge system functions. The following outlines a way of breaking down the fire dynamics and deluge system functions into understandable segments (see figure 15):

a. Ignition Time -- T0: The start of ignition. Ignition of an item is defined as self-sustained deflagration.

b. Ignition To Sensing Threshold Time -- T1: The time from ignition until the buildup of energy reaches the sensing threshold of the detector saturation. This is dependent upon the configuration of the item being protected. For example, the ignition of propellant from the bottom of a hopper may require more than a second to reach the surface of the propellant where it can be sensed by a detector. If ignition occurred on the surface, the ignition to sensing threshold period would be much less -- in the millisecond range.

c. Ignition To Detector Response Time -- T2: The time from ignition to transmission of the signal to the controller.

d. Ignition To Controller Response Time -- T3: The time from ignition to transmission of signal to deluge valve squib or solenoid.

e. Ignition To Valve Opening Time -- T4: The time from ignition to the opening of the deluge valve permitting water to flow.

f. Ignition To First Water at the Nozzle Time -- T5: The time from ignition to the first flow of water from the critical nozzle(s). This is usually the nozzle(s) closest to the hazard or as determined by a hazard analysis.

g. Ignition To First Water on Target Time -- T6: The time from ignition to the first drops of water to strike the target from the critical nozzle(s). There is usually an initial stream of water, followed by a break in the flow, followed by a full flow pattern.

h. Ignition To Full Flow Water On Target Time -- T7: The time from ignition to a fully-developed spray of water strikes the target area.

i. Extinguishment Time -- T8: The time from ignition to termination of the deflagration.

36. Deluge system response time should be redefined as total response time. This is the total time lapse from detector sensing threshold response to full flow of water on the target area (T1-T7). Total response time consists of two segments -- detection time (T1-T4) and water delivery time (T4-T7).

a. Detection time is the time from detector sensing threshold of the fire to the time that the signal is amplified and fires the primer in the water control valve or opens the solenoid valve (T1-T4). The detection time is the fastest phase, and under ideal conditions, can be accomplished in as little as 10 milliseconds. Factors effecting detection time include:

(1) Distance between detector and target.

(2) Type of flame and amount of smoke.

(3) Signal processing time.

(4) Detector sensitivity.

b. Water delivery time is the time required from primer firing or solenoid valve opening to the time a fully developed spray of water strikes the target (T4-T7). It is the source of most of the time consumption and is dependent on several factors:

(1) The completeness of water prime of the piping system from the valve to the nozzles. Tests show this is a vitally important factor, since an air pocket constituting only a small percent of the total volume of the system can cause drastic increase in operating time.

(2) Water pressure. Both analysis and tests show that all other factors being equal, the water delivery time is inversely proportional to the square root of water supply pressure. This would mean, for example, that if the supply pressure on a specific system were increased from 50 psi to 100 psi, the water delivery time would be reduced by about 40 percent with all other factors being equal.

(3) The distance from the nozzle to the hazard.

37. Two methods frequently used to check response time of ultra high-speed deluge systems are the digital timer and the high-speed video recording system:

a. The digital timing system consists of a timer connected to a timing circuit consisting of a saturating UV or IR source at the detector and a waterflow switch to measure the first flow of water at the nozzle (see figure 16). Controller output could also be measured. The timer is started the instant the UV or IR saturating source is activated, and the timer is stopped the instant first water leaves the critical nozzles (T1-T5). Several devices can be used to measure first water at the nozzle. One consists of a light metal disc approximately 2 inches in diameter held between two electrically conductive contacts. The water from the nozzle pushes the disc out of the contacts opening the circuit and stopping the timer. The measurement of first water on the target is more difficult (T1-T6). One method would be to place two electrically conductive screens on top of each other, but sufficiently separated so that a complete circuit is made only when a few drops of water pass through the screens. The screens would need to be large enough to ensure the first water hit them, possibly 1-foot square. The digital timer is well suited for routine measurement of response time by maintenance technicians at Army ammunition plants: it is inexpensive, easy to operate, and can be quickly set-up and torn down.

b. The high-speed video system consists of a camera, recorder, and monitor. The system is capable of recording 60 to 300 frames per second or up to 3.3 frames per millisecond (see figure 17). The system provides a practical way to measure total system response time from initiation to suppression (T0-T8). The first visible indication of an incident can be identified long before the detector is saturated. The digital timer can only be activated when the detector is saturated. The high-speed video recording system costs less than $20,000. It can also be rented. It is the ideal tool for measuring total system performance (T0-T8), compliance with criteria specified in contract documents, evaluating new or modified systems, and determining total system response time. This seems to be acceptable by most authorities for testing deluge systems in the field and also for periodic maintenance testing. This will also provide a baseline for checking system response time during flow tests on and after a system has been inactive for an extended period of time or a system has been modified or worked on.

38. When response time and the method to measure are clearly defined, it is possible and feasible to call out a performance specification in contract documents (see figure 18).

a. Based upon my recommendation, the section of the U.S. Army Materiel Command Safety Manual dealing with deluge system response time was changed to read:

> "In lieu of testing, a small deluge system (design flow rate of 500 GPM or less) shall have a response time of 100 milliseconds and a large deluge system (design flow rate of more than 500 GPM) shall have a response time of 200 milliseconds. The results of the tests or the use of the 100 or 200 millisecond response time will be reflected in safety submissions for facilities and will be retained on file by the installation for the life of the system. Response time is defined as the time from the sensing of a detectable event by the detector; e.g., detector output to the beginning of water flow from the critical nozzle(s) closest to the target. This will normally be the nozzle(s) closest to the hazard or as determined by the hazard analysis."

b. As a result of a recent seminar on ultra high-speed deluge systems, I have recommended:

(1) If a hazard analysis indicated a response time of 100 or 200 milliseconds is too long, a shorter response time should be specified.

(2) Measurement of response time should start with detector input. When a digital timer is used, a saturating UV or IR source should be used.

c. During the recent seminar, several deluge system vendors indicated an interest in standardizing on a digital timer system used to measure response time. Many users also indicated an interest. I strongly support this effort and will recommend the U.S. Army Materiel Command support it.

39. To establish and maintain an acceptable level of deluge system performance and minimize problems such as false activations, the following items should be considered:

a. People, communication, and training.

(1) The technical organization responsible for deluge systems must be identified and maintained to ensure deluge systems are adequately designed, installed, and maintained. Army ammunition plants that have established and maintained such a group have reduced their problems with false activations and problems with deluge systems.

(2) Continuity with outside agencies involved with deluge system design, installation, and maintenance should be maintained.

(3) Training of technicians and engineers is vital. They must be sent to vendor schools on a periodic basis to keep abreast of new developments and changing technology.

(4) Transfer of information between using installations and vendors is vital so they can learn from each other's experience.

b. Design and installation. The design and installations of ultra high-speed deluge systems for ammunition applications involves a technology which is substantially different from that associated with automatic sprinkler systems. Because, due the speed of water delivery from all of the nozzles, ultra high-speed deluge systems are highly dependent on the detection system, piping network, nozzles, and water supply characteristics, the design and the installation of ultra high-speed deluge systems must be performed by experienced designers and installers who thoroughly understand the limitations and capabilities of these systems.

(1) Specifications and contract documents should not go into detailed design of the system, but should clearly define the performance criteria and how they will be measured. These should include:

(a) Detection system.

- Areas to be viewed.
- Source of flash or flame to be detected.
- System logic required.
- Supervisory requirements.
- Testing requirements.

(b) Extinguishing system.

- Area to be protected.
- Water application rate or density.
- Testing requirements.

(c) Other needed information.

- Approximate location of connection to water supply system.
- Water supply line layout and valve locations.
- Location of control panel.
- Available static and residual water pressure (at the minimum required flow rate).
- Need for emergency power.
- Remote signal requirements for alarm systems and process equipment shutdown.
- Required response time.

(2) The pipe diameter, length, number of bends, and friction coefficient contribute to the volume of water that can be transported at an effective pressure through the piping system. Pipe runs and bends should be kept to a minimum, and all horizontal runs should be sloped at least 3/4 inch per 10 feet of run, with air bleeders at all high points. Removal of all trapped air is very important. The main water supply line and pilot line (for solenoid-operated valves) should have strainers.

(3) Failure to follow vendor guidelines during design, installation, and maintenance causes an increase in false activations and related problems.

(4) Limit the overall size of the system (both detectors and nozzles) to smallest practical size possible. This should be below the vendor recommendation maximum. This tends to increase system stability and minimizes false

activations and related system problems as it degrades through normal aging and during layaway.

(5) Design changes should be made vary cautiously and field tested on a prototype system. Because there are so many variables, this permits the evaluation of one or two variables at a time.

(6) A complete set of detailed shop drawings, hydraulic calculations, operating instructions, and similar material should be provided by the contractor.

(7) A competent Government inspector should verify the deluge system is being installed in accordance with contract requirements.

(8) Controllers should be located in separate enclosures to reduce false activations due to electromagnetic energy generated by other electrical devices.

(9) The controller must be programmed for the number of detectors to be used. Failure to do so can affect the internal test features and reliability of the controller.

(10) Process equipment should be interlocked through controller fault circuitry, including the main water supply valve.

(11) Conduit carrying detector cable and detector tubes should be sealed. Seals should also be installed at each detector itself. Failure to do so will permit moisture in the detectors and conduit, causing false activations and system problems.

(12) Automatic inspection features built into detectors and controllers are cost effective because they help identify problems and faults in a more timely manner and mandate a better preventive maintenance policy.

(13) Ultraviolet detectors for ultra high-speed deluge systems should be located to provide two levels of protection. One or more detectors should be placed as close as physically posible to the most likely source(s) of ignition. They should be located so the detector's field of view is not blocked by shielding, equipment, or personnel. One or more additional detectors should be located to provide general area coverage of the cubicle or bay, on the assumption that an ignition could occur at other points within the area. Ultraviolet and IR detectors are optical devices, and as such respond to the attenuation laws of optics, doubling the distance between the detector, and the flame will reduce the radiation perceived to one-fourth; conversely, reducing the distance by one-half results in four times more radiation to the detector. The need to locate detector(s) as close as possible to the hazard and not block their view of the hazard were driven home in a series of tests conducted by a leading detector manufacture point. In one test, 10 grams of black powder was ignited. There was an almost 100-percent increase time between 5 and 10 feet (1.75 and 3.5 meters) and the almost 200-percent increase between 5 and 15 feet (1.75 and 5.25 meters). The detector response times were:

5 feet (1.75 meters)...27 milliseconds
10 feet (3.5 meters)...54 milliseconds
15 feet (5.25 meters)...75 milliseconds
20 feet (7 meters)...78 milliseconds

In another test, 10 grams of black powder was ignited. The fire was viewed by three identical detectors and controllers located 10 feet (3.5 meters) from the fire. The detectors had a clear view, partially obstructed view, and completely obstructed view respectively of the target. There was an almost 100-percent increase in response time when the view is partically or completely blocked. The detector response times were:

Clear view......20 milliseconds
Partial view....38 milliseconds
Blocked view....40 milliseconds

(14) Ultraviolet contaminants that are present in the environment can accumulate on the optical surfaces of the detector. An accumulation of certain materials, sometimes barely visible to the naked eye, can cause a significant reduction in the level of UV that reaches the sensor tube of the detector. This could make the detector nearly "blind" to UV radiation. An electronic self-testing feature has been designed to guard against such an occurrence. The system generates a calibrated UV test beam from a small tube that is located inside the detector housing beside the UV sensor tube. The test beam passes outside the viewing window of the detector and is then reflected back through the window and into the UV sensor. The sensor tube then generates an output signal that is sent to the controller, where the intensity is evaluated to determine the relative cleanliness of the viewing window. The test signal does not interfere with the normal functioning of the detector, since it is considerably weaker than a UV fire signal. Therefore, no danger of a false alarm exists. In addition, if a fire should occur during test, a fire signal will immediately be generated. The system continuously checks the optical surfaces, electronic components, and interconnecting wiring of the detector. Any malfunction is detected in a matter of seconds. The controller responds by registering a fault output and sounding a trouble alarm to alert personnel that a problem has occurred.

(15) Ultraviolet detectors are sensitive to weld arcs, lightning, X-rays (gamma radiation), cosmic and background radiation, and high electrostatic charges. In some applications, the system may have to be shut down to prevent false alarms when these sources of interference are present. They should be located away from the horizontal plane, and not aimed toward doors or windows.

(16) Ultraviolet radiation will not transmit through smoke, water vapor, acetone, regular glass, plexiglass, or oil.

(17) Detector and prime circuit cabling should be the shielded type and placed in conduit separated from all other wiring. Ensure that detector cabling and cable shielding are installed and grounded according to vendor specifications. Proper cable installation and grounding minimize system problems and false activations.

(18) Deluge valves should be located as close as possible to the hazard. The water travel time from the nozzle to the target is the longest component of response time.

(19) Critical nozzles should be located as close as possible to the hazard. The water travel time from the nozzle to the target is usually the longest component of response time.

c. Maintenance and testing procedures.

(1) A good preventive maintenance program is required. Experience has shown that increasing the time period beyond 6 weeks results in a significant increase of false activation and other system problems. A tri-service manual entitled Maintenance of Fire Protection Systems (TM 5-695/NAVFAC MO-117/Air Force AFM 91-37) provides guidance on the inspection and testing of fire protection systems. The following items should be considered when establishing maintenance procedures:

(2) System checks:

- Measure all voltages.
- Pull all controllers in by-pass and check for loose wires and/or relays.
- Clean all dirt and debris from console.
- Relamp console.
- Spot check conduit fittings for moisture and/or loose wire nuts.
- Check squib operated valve o-rings (damp or wet primers).
- Check OS&Y Valve Limit Switches on water supply lines.

(3) Detectors.

- Remove each lens and clean.
- Remove each barrel and check grounding springs, when used.
- Tighten each terminal screw in sensors.
- Clean and inspect all optical integrity rings.
- Check for moisture and/or corrosion inside sensor housings.
- Check each detector proper alignment.
- Check housing for continuity.
- Reactiviate system and check for problems.

(4) Flow tests should be conducted:

- Annually for active systems.

- After major maintenance or modification.

- After reactivating an inactive system.

(5) Priming water - squib-operated system

- Check weekly.

- Open vent.

- Crack priming value.

- Allow water to flow for a few minutes, close priming value first, then the vent value.

(6) Squib-operated value.

- Trip system at least annually by firing primers.

- Replace primers at least annually.

(7) Solenoid-operated valves.

- Trip system at least annually.

- Check solenoid valve for leaks.

40. The development of a computer model would aid in the design of ultra high speed deluge systems. The variables listed in paragraph 29 and those listed below should be considered:

- Water flow rate.

- Time to detection.

- Extinguishment time.

- Water pressure.

- Pipe size.

- Pipe configuration.

- Number of nozzles.

- Nozzle design.

- Deluge valve location.

- Pressure rise of the energetic material.

- Change in temperature.

- Process equipment layout and shape.

- Packing density of the energetic material.

- Volume of energetic material.

- Heat of combustion.

- Grain shape and size.

- Water travel distance from the nozzle to the hazard.

41. The need for a "portable" deluge system has been identified by several Army commands and is being evaluated by the U.S. Army Armament, Munitions and Chemical Command Safety Office. Two configurations appear to be needed. One that is completely self-contained with its own UV detectors, nozzles, and water supply. The other would have the detectors and nozzles but would require water from the building water system. These systems could be used where the installation of a permanent deluge system is not feasible or cost effective. The protection provided by a "portable" deluge is very limited (approximately 3 meters by 3 meters) and is not a substitutefor permanently installed systems. Inspection, maintenance, and renovation operations taking place in depots and field locations would be prime candidates for portable deluge systems.

42. The following areas require additional work and effort:

- Computer modeling.

- Development of a "portable" deluge system.

- Technical guidelines and performance specifications.

- Performance evaluation procedures.

- Determining causes of false activations.

- Information exchange between vendors and users.

- Evaluation of new deluge system technology.

43. These actions can best be accomplished by:

- Updating technical manuals and regulations.

- Formation of an informal working group.

- Holding seminars and workshops on a regular basis.

- Having a central organization be responsible to monitor developments, oversee research programs, develop a data base, and pass information to users and vendors.

44. The technical reports in appendix A and the references in appendix B were utilized in the preparation of this paper. Additional technical material and assistance was provided by the following persons:

a. Mr. Louis Joblove and Mr. Manuel Avelar, Amman and Whitney Consulting Engineers.

b. Mr. James Brazell, Mr. Stanley Straker, and Mr. Mervin Opel, ICI Americas, Inc., Indiana AAP.

c. Mr. Gene Burns, Day and Zimmerman, Inc., Lone Star AAP.

d. Mr. Gary Fadorsen, Automatic Sprinkler Corporation.

e. Mr. Joe Priest, Grinnell Fire Protection.

f. Mr. Ken Klapmeier, Detector Electronics.

g. Mr. Stan Keadle, Mason and Hanger.

45. The point of contact for this action is Mr. Robert Loyd, AMSMC-SFP, AV 793-2975, commercial (309) 782-2975.

UV DETECTOR

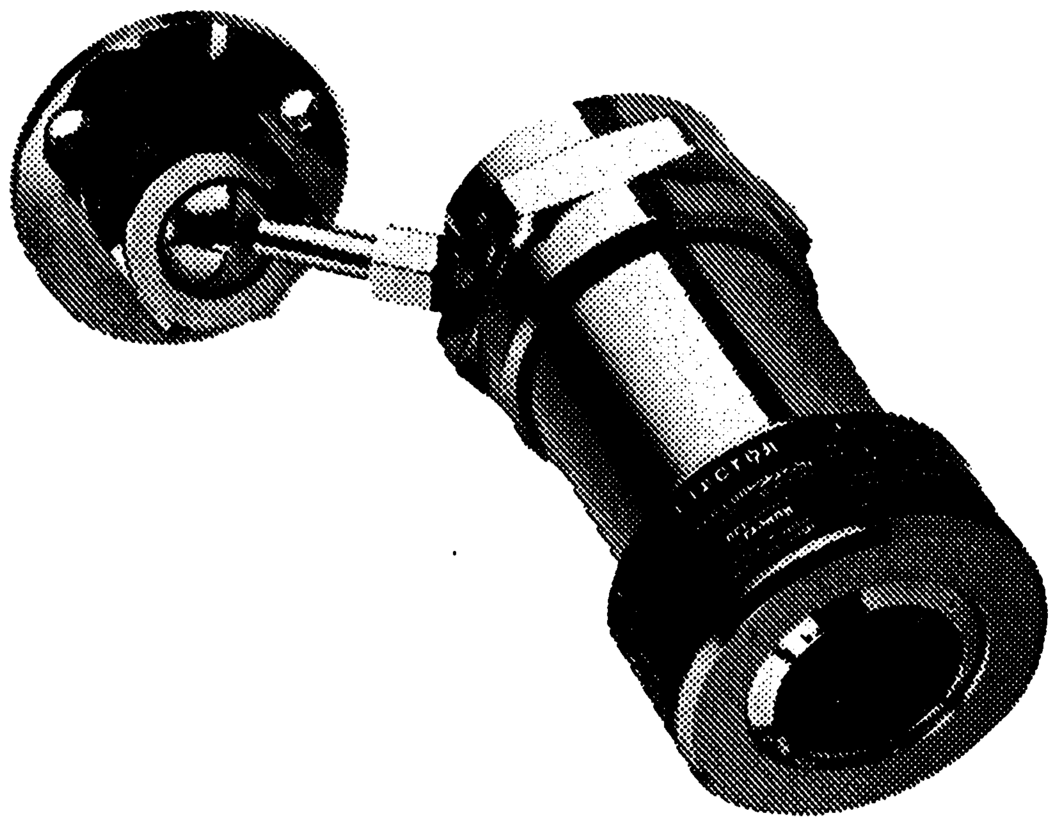


FIGURE 1

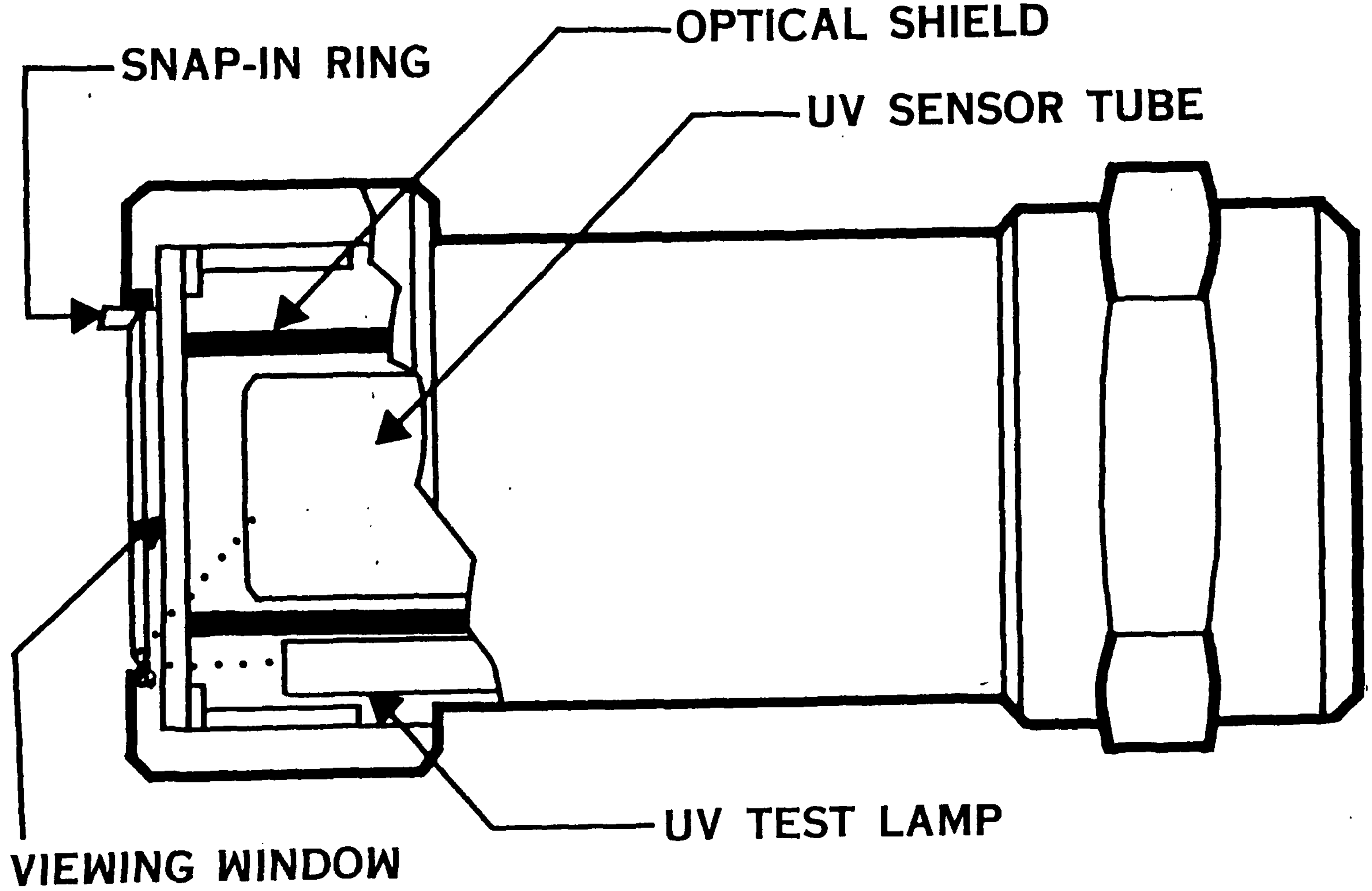

SNAP-IN RING
OPTICAL SHIELD
UV SENSOR TUBE
UV TEST LAMP
VIEWING WINDOW

FIGURE 1A

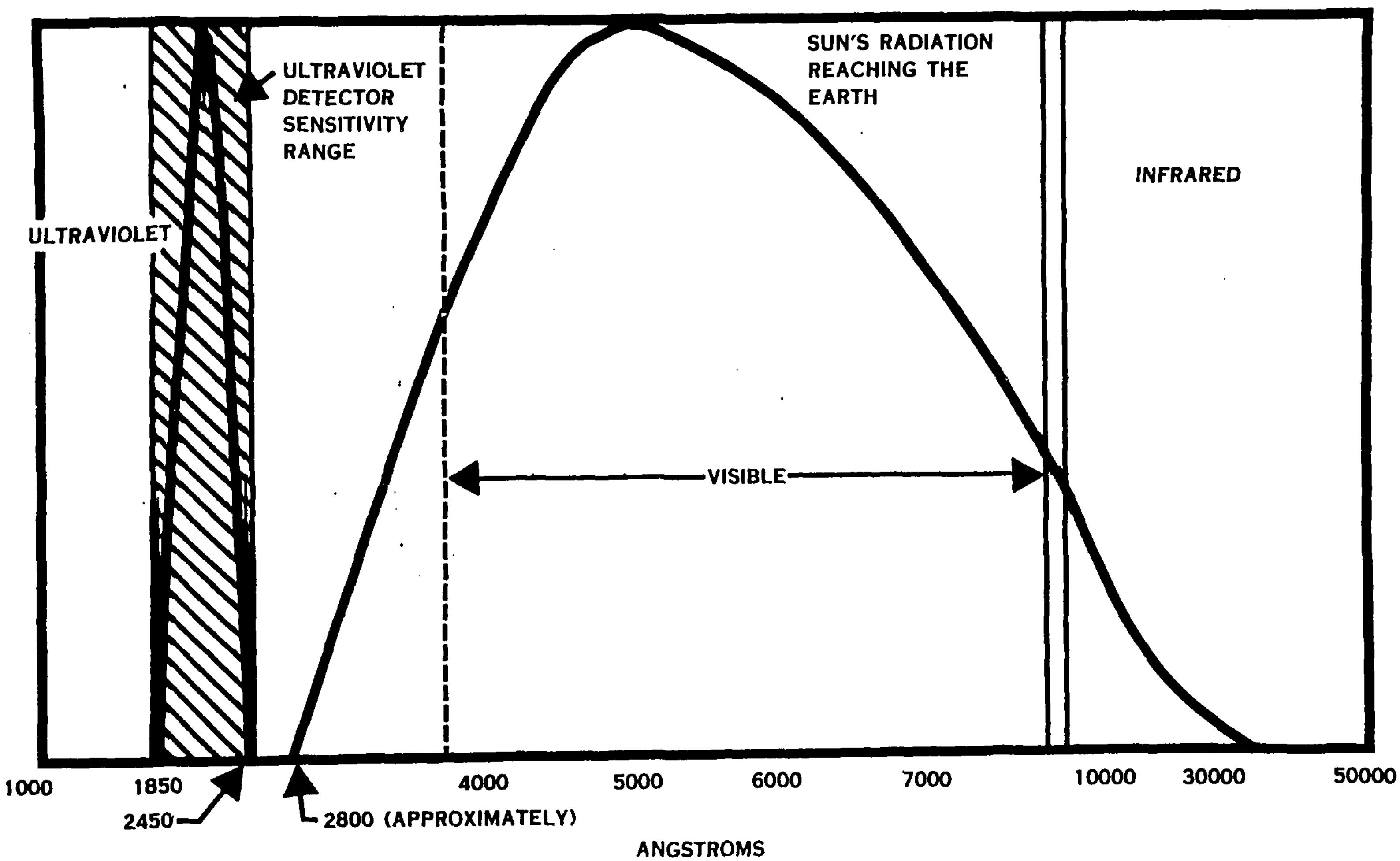
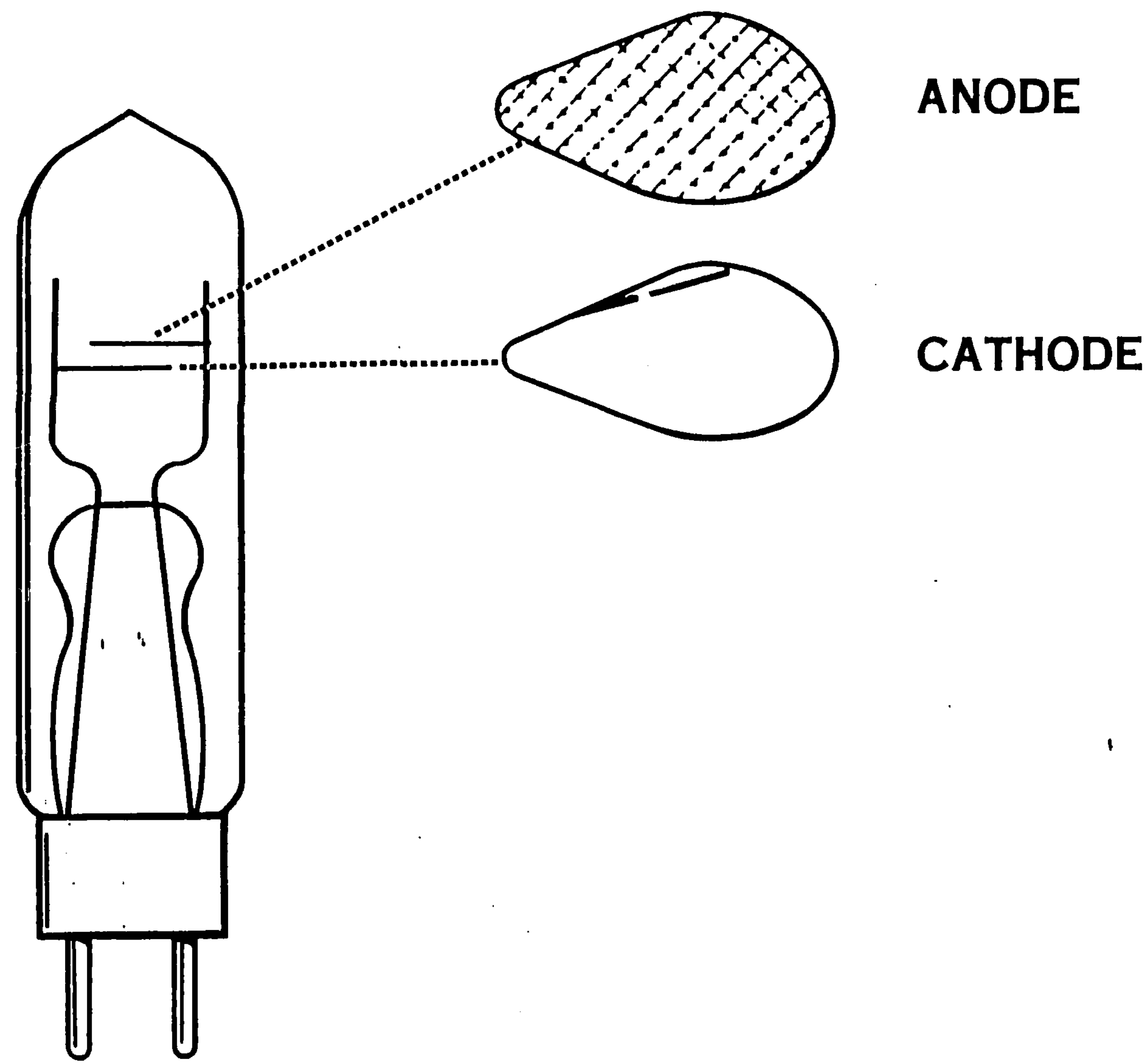

ULTRAVIOLET
ULTRAVIOLET DETECTOR SENSITIVITY RANGE
SUN'S RADIATION REACHING THE EARTH
INFRARED
VISIBLE
1000
1850
2450
2800 (APPROXIMATELY)
4000
5000
6000
7000
10000
30000
50000
ANGSTROMS

FIGURE 2

UV DETECTOR TUBE



UV CONTROLLER

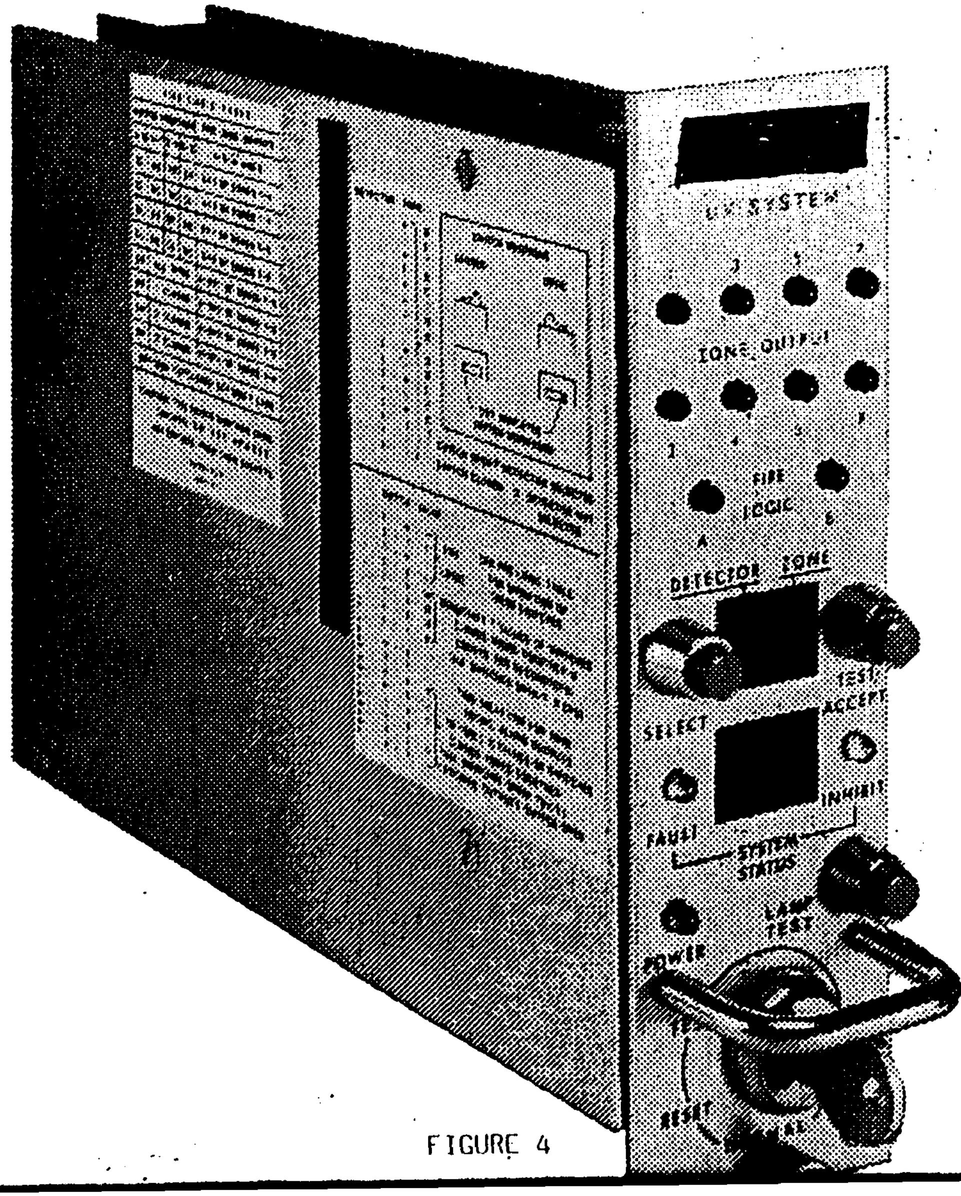


FIGURE 4

IR DETECTOR

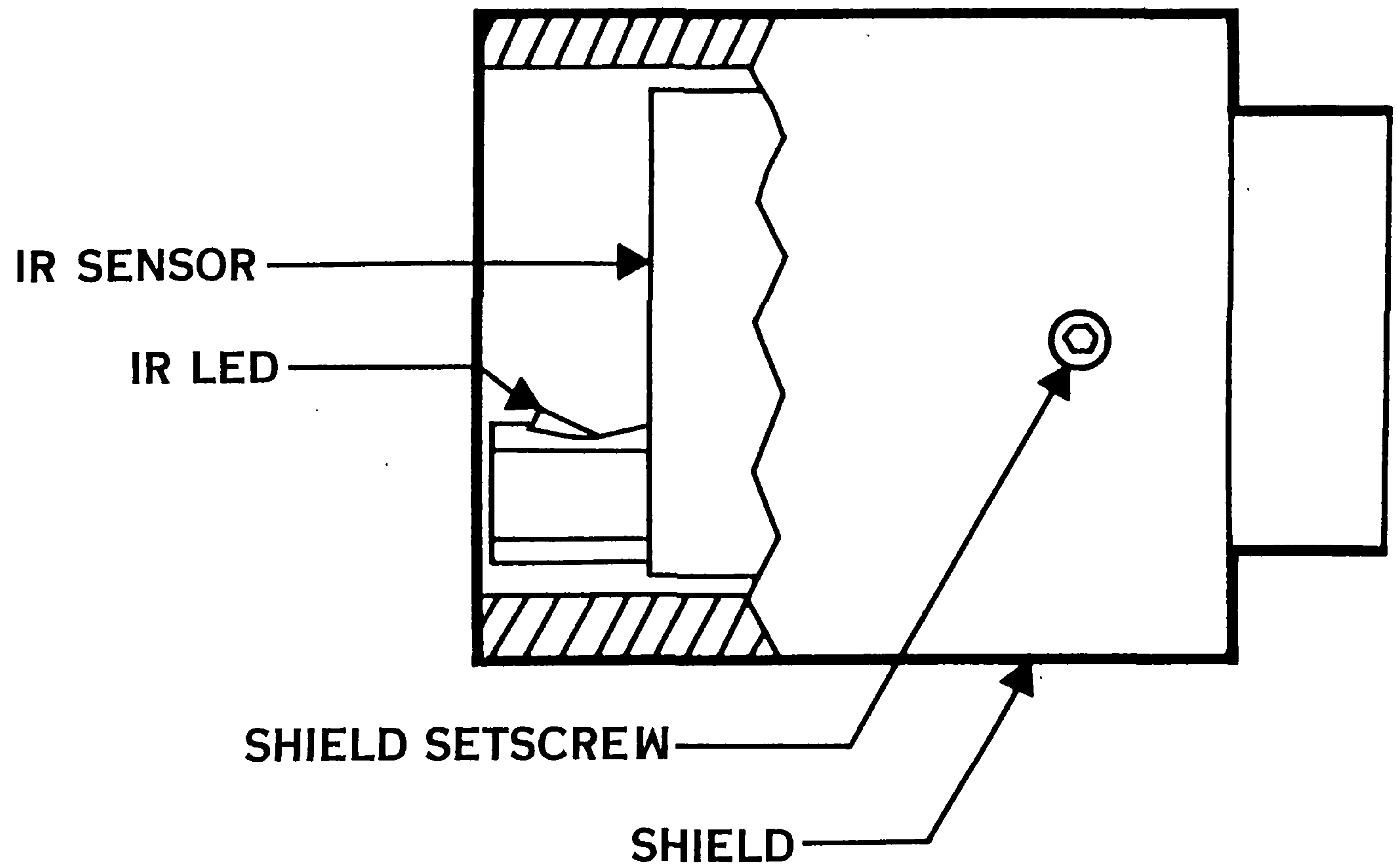


FIGURE 5

IR CONTROLLER

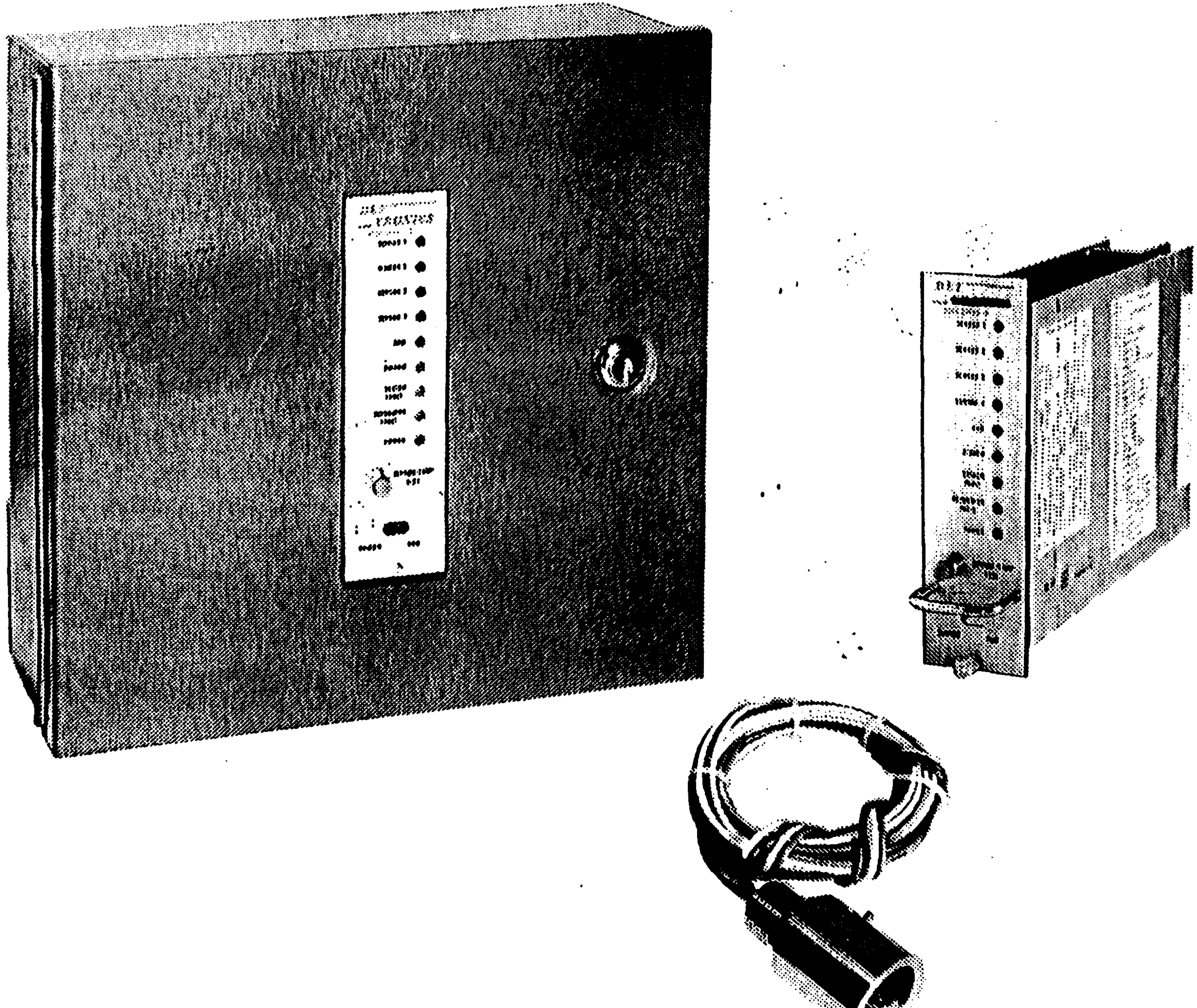


FIGURE 5A

RADIATION SPECTRUM

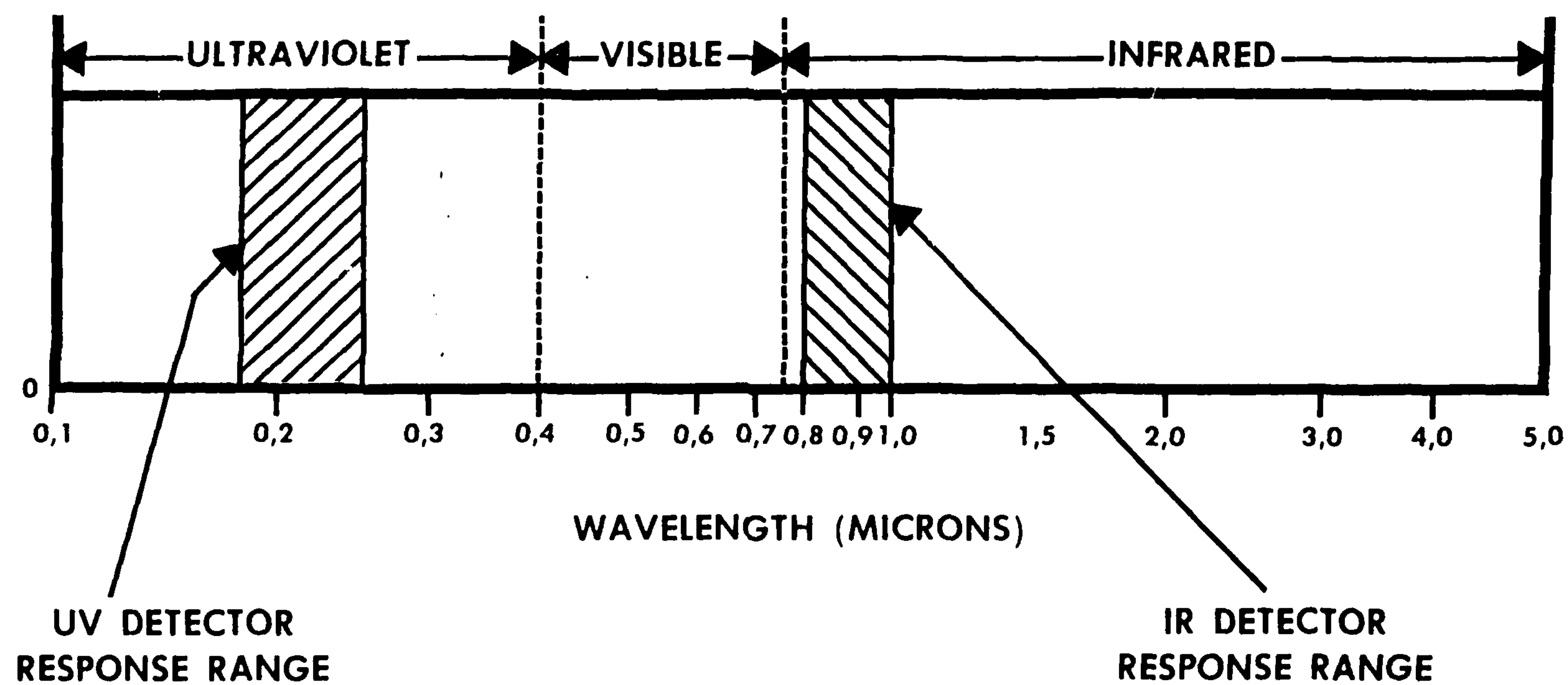


FIGURE 6

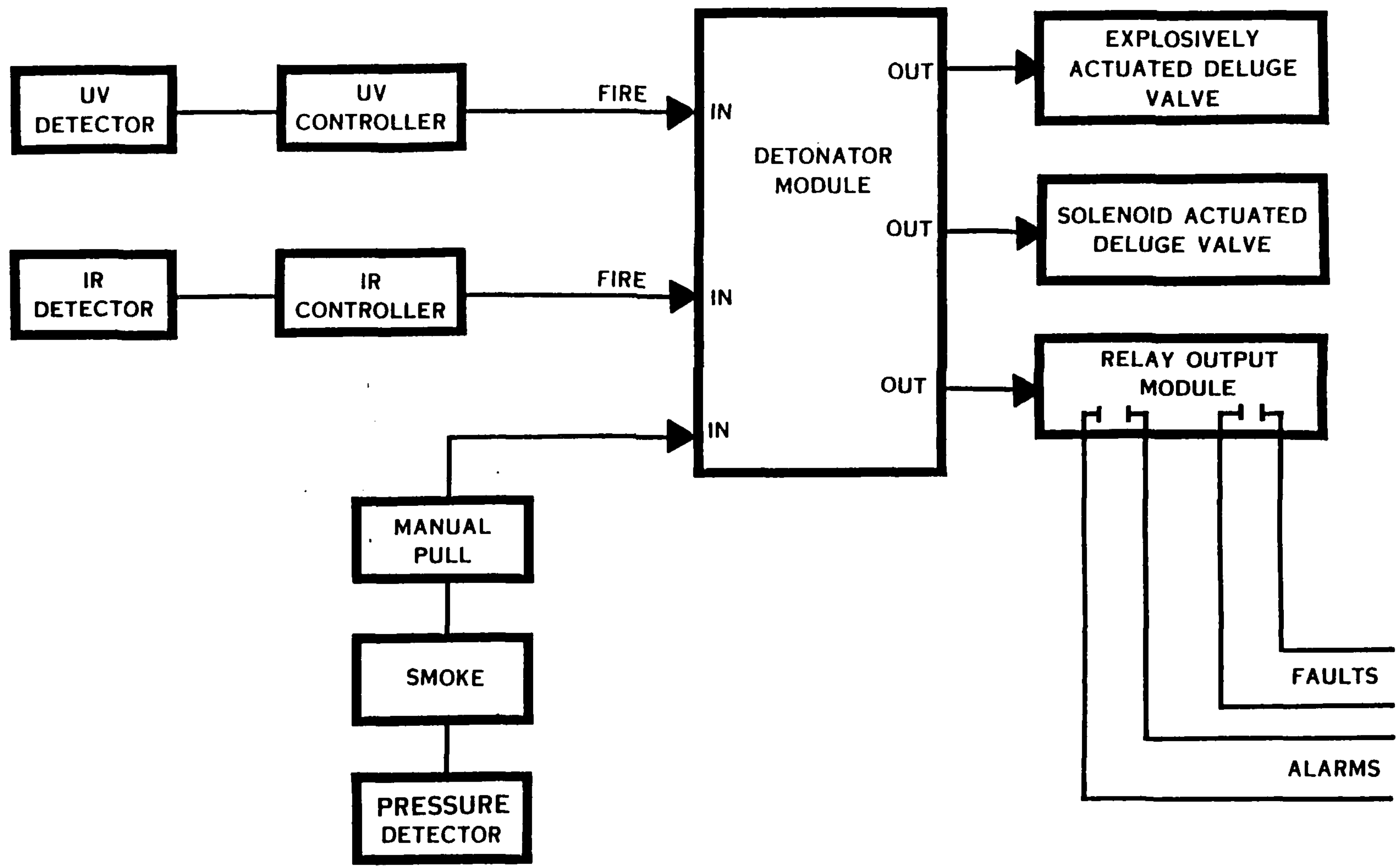

UV DETECTOR
UV CONTROLLER
FIRE
IR DETECTOR
IR CONTROLLER
FIRE
MANUAL PULL
SMOKE
PRESSURE DETECTOR
IN
IN
IN
DETONATOR MODULE
OUT
OUT
OUT
EXPLOSIVELY ACTUATED DELUGE VALVE
SOLENOID ACTUATED DELUGE VALVE
RELAY OUTPUT MODULE
FAULTS
ALARMS

FIGURE 6A

TYPICAL SQUIB SYSTEM

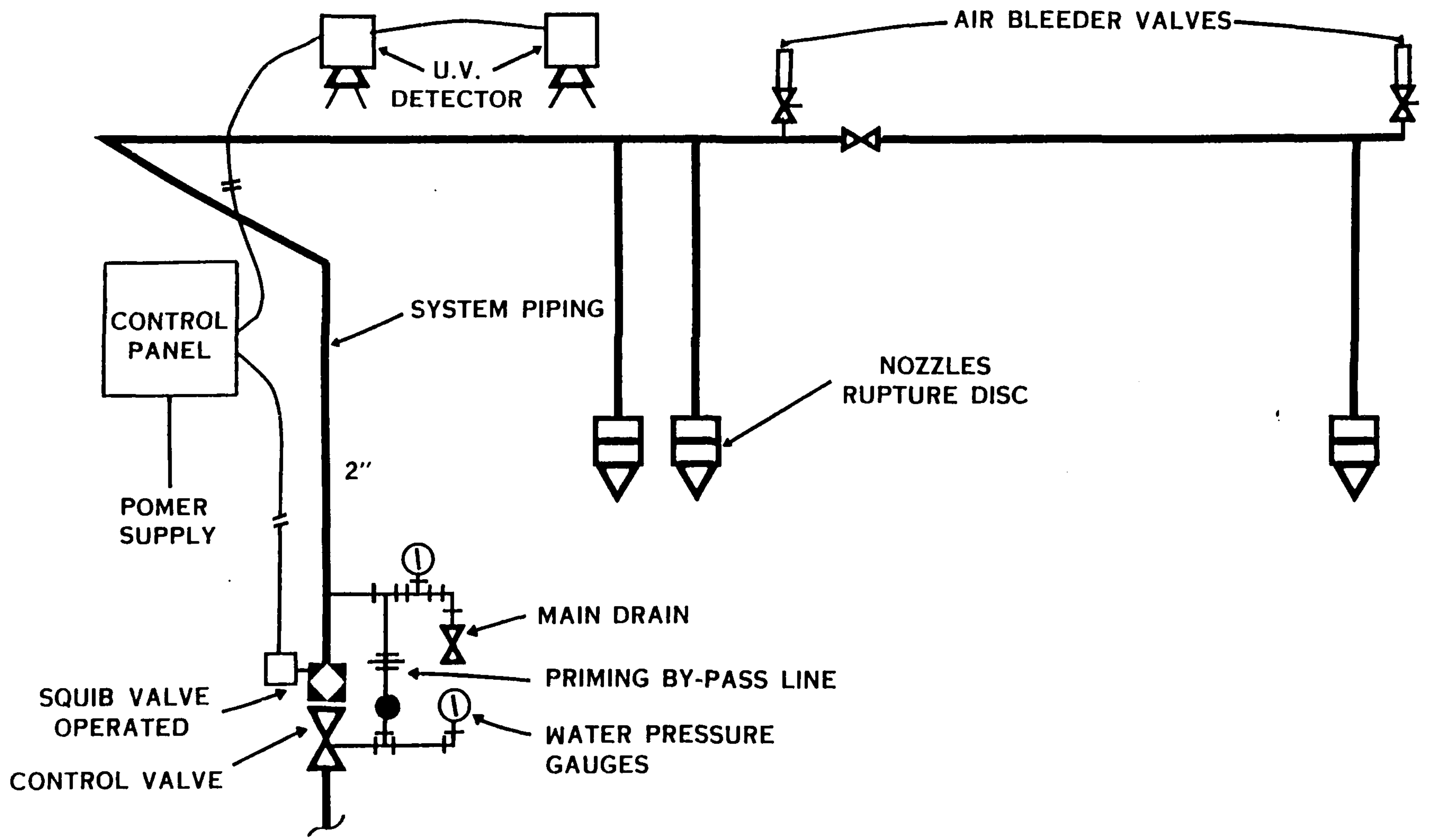


FIGURE 7

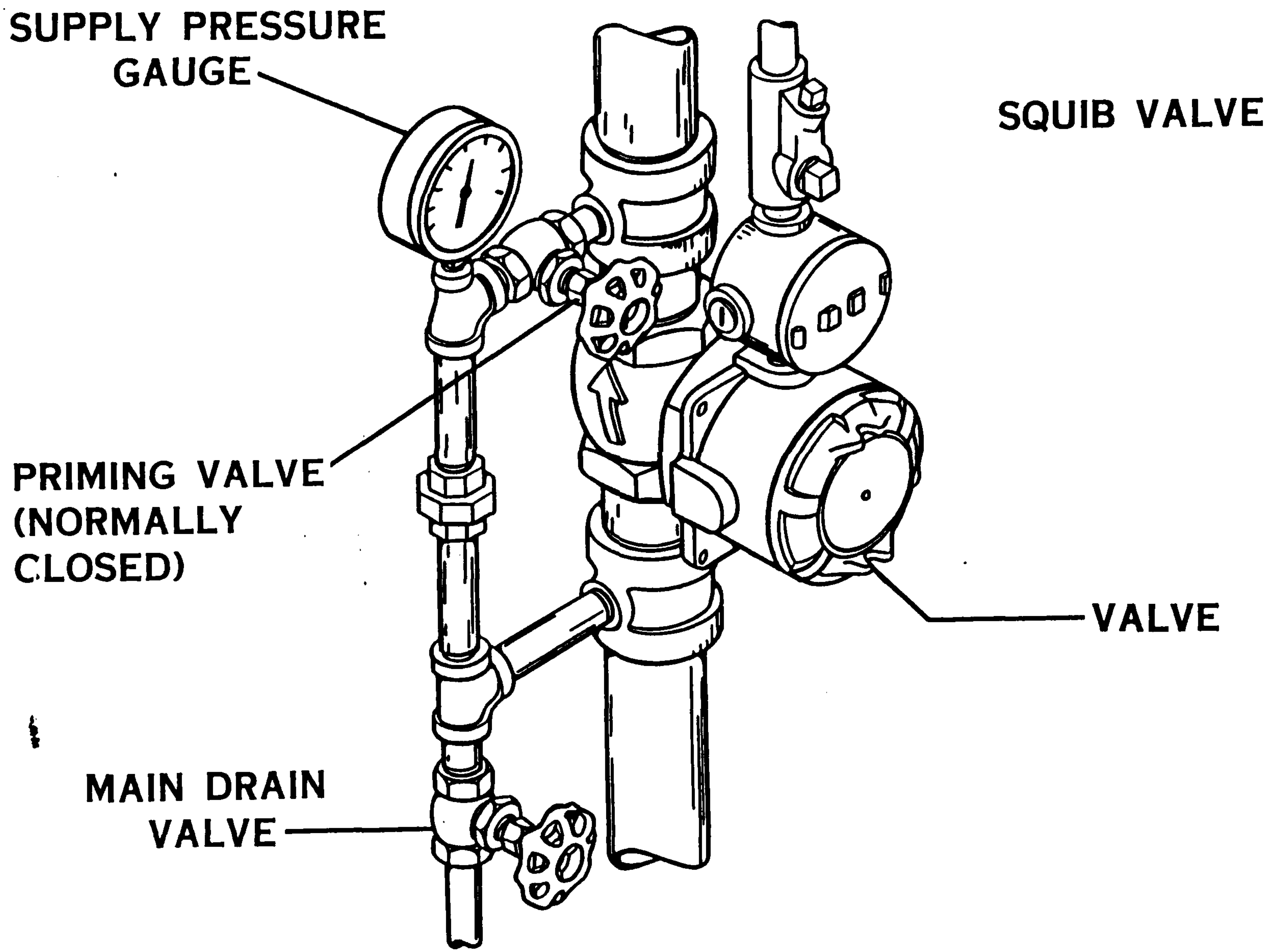

SUPPLY PRESSURE
GAUGE
SQUIB VALVE
PRIMING VALVE
(NORMALLY
CLOSED)
VALVE
MAIN DRAIN
VALVE

FIGURE 8

2 INCH SQUIB VALVE

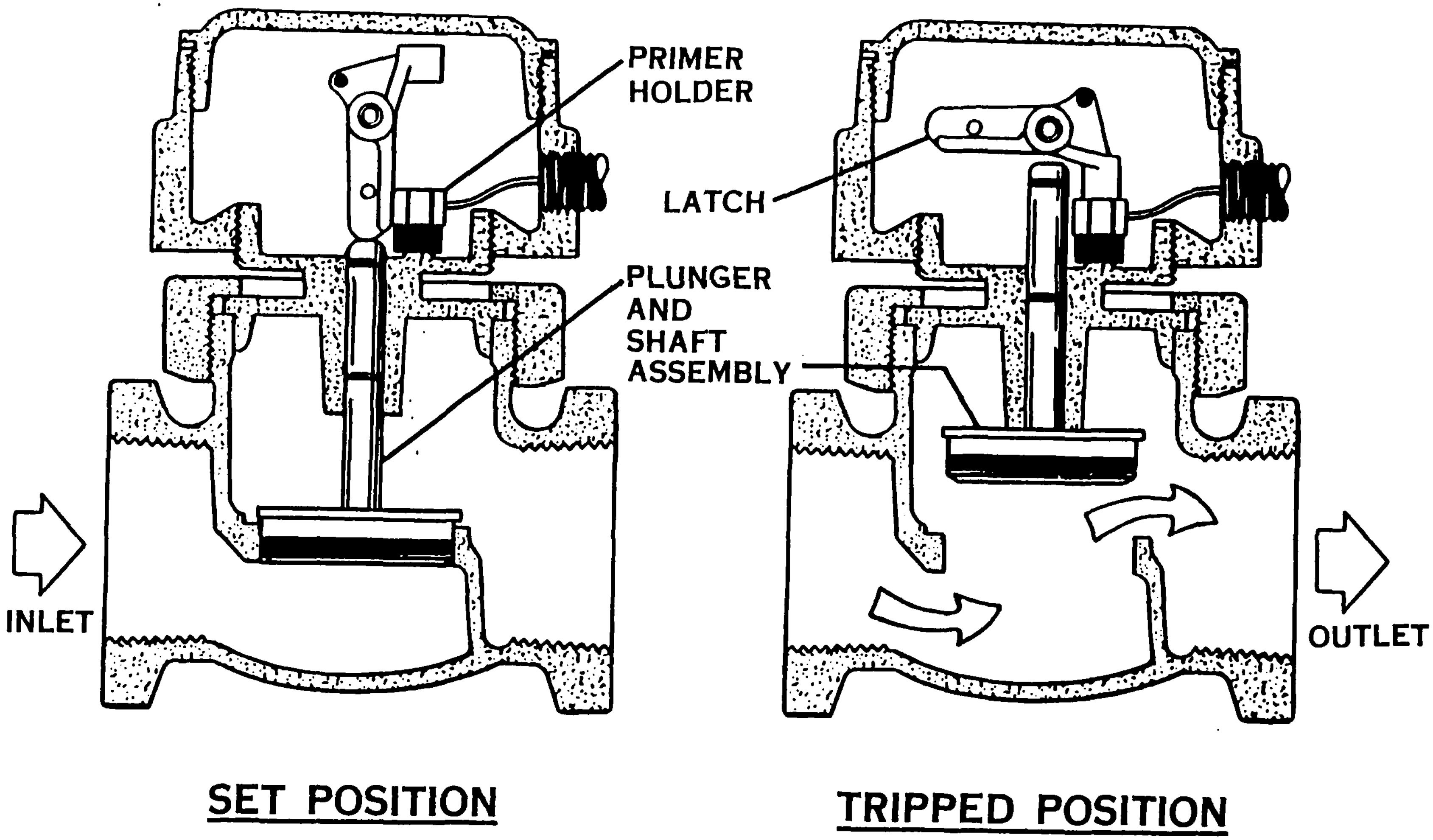


FIGURE 9

TYPICAL SOLENOID (PILOT) SYSTEM

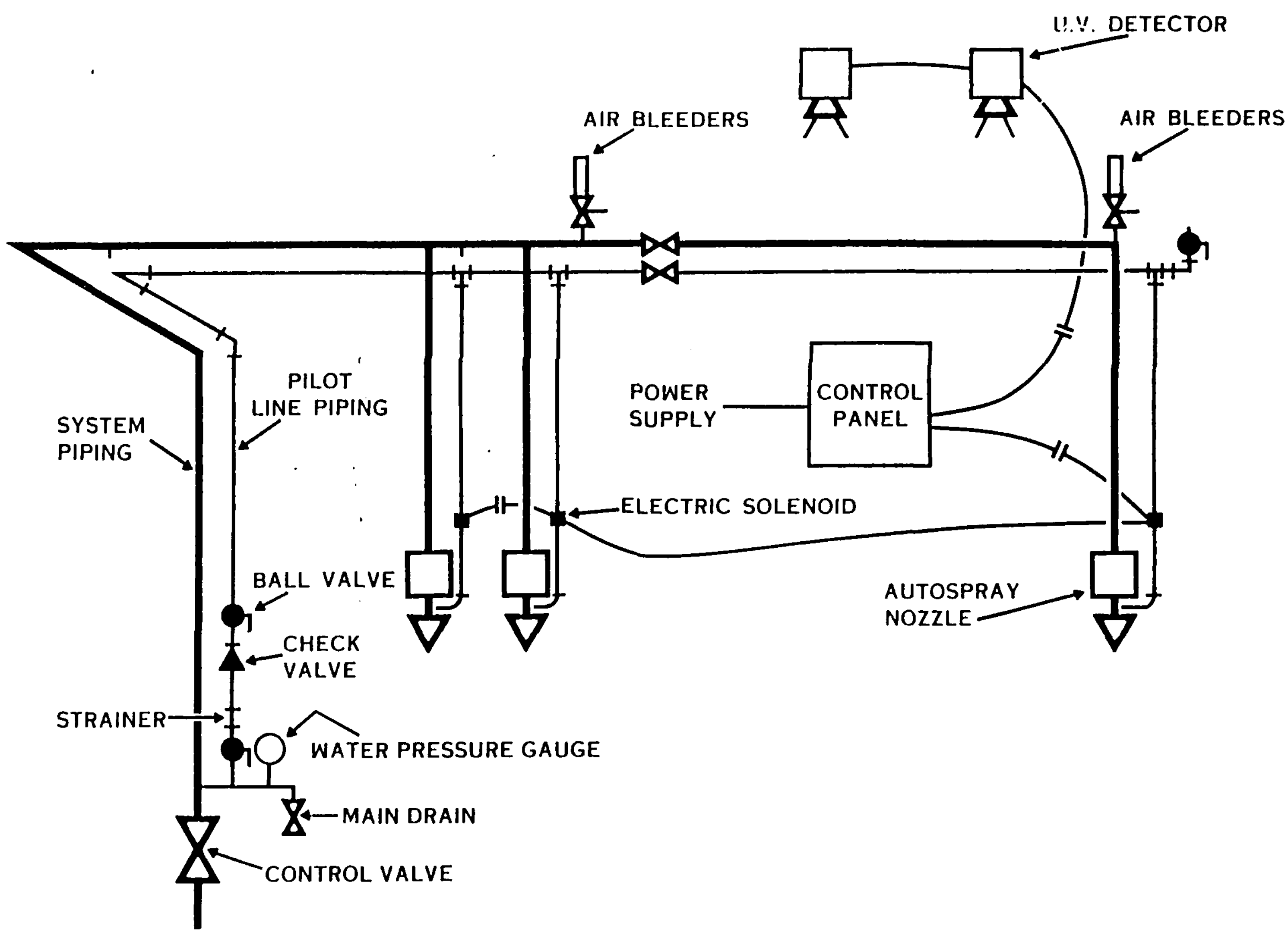


FIGURE 10

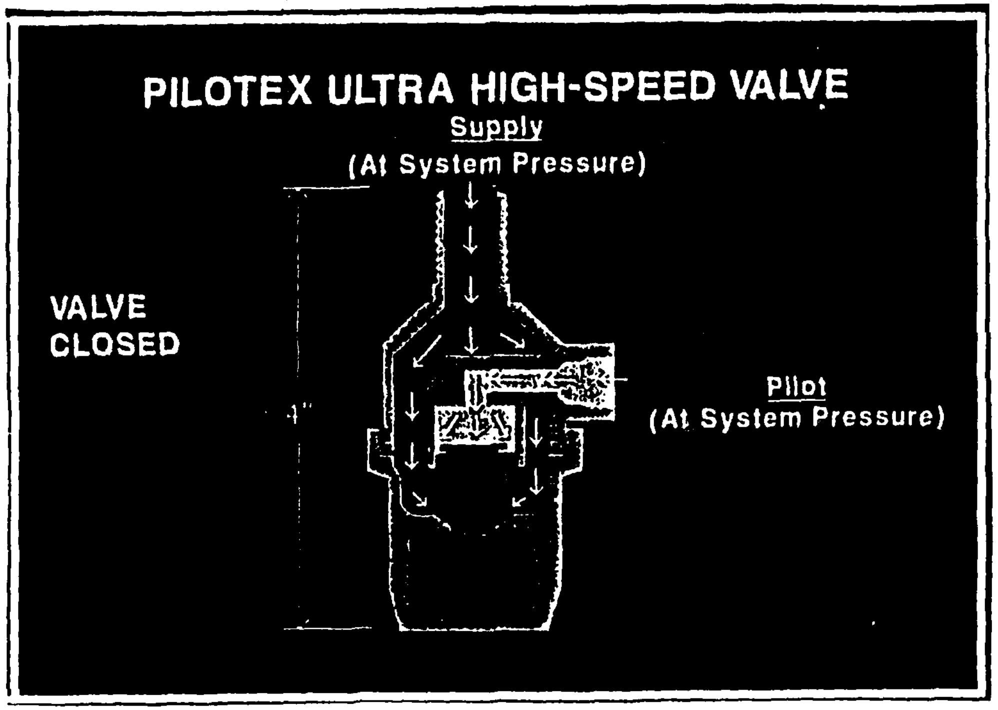

PILOTEX ULTRA HIGH-SPEED VALVE
Supply
(At System Pressure)
VALVE
CLOSED
Pilot
(At System Pressure)

FIGURE 11

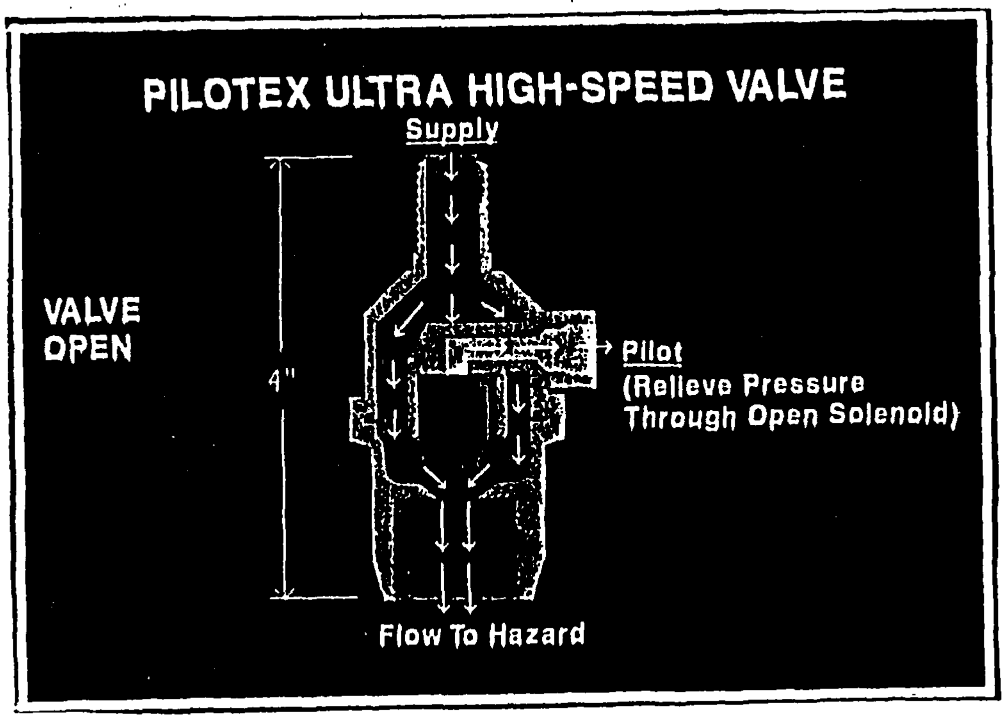

PILOTEX ULTRA HIGH-SPEED VALVE
VALVE OPEN
Supply
4"
Pilot
(Relieve Pressure
Through Open Solenoid)
Flow To Hazard

FIGURE 12

EXPLOSIVE RUPTURE DISC

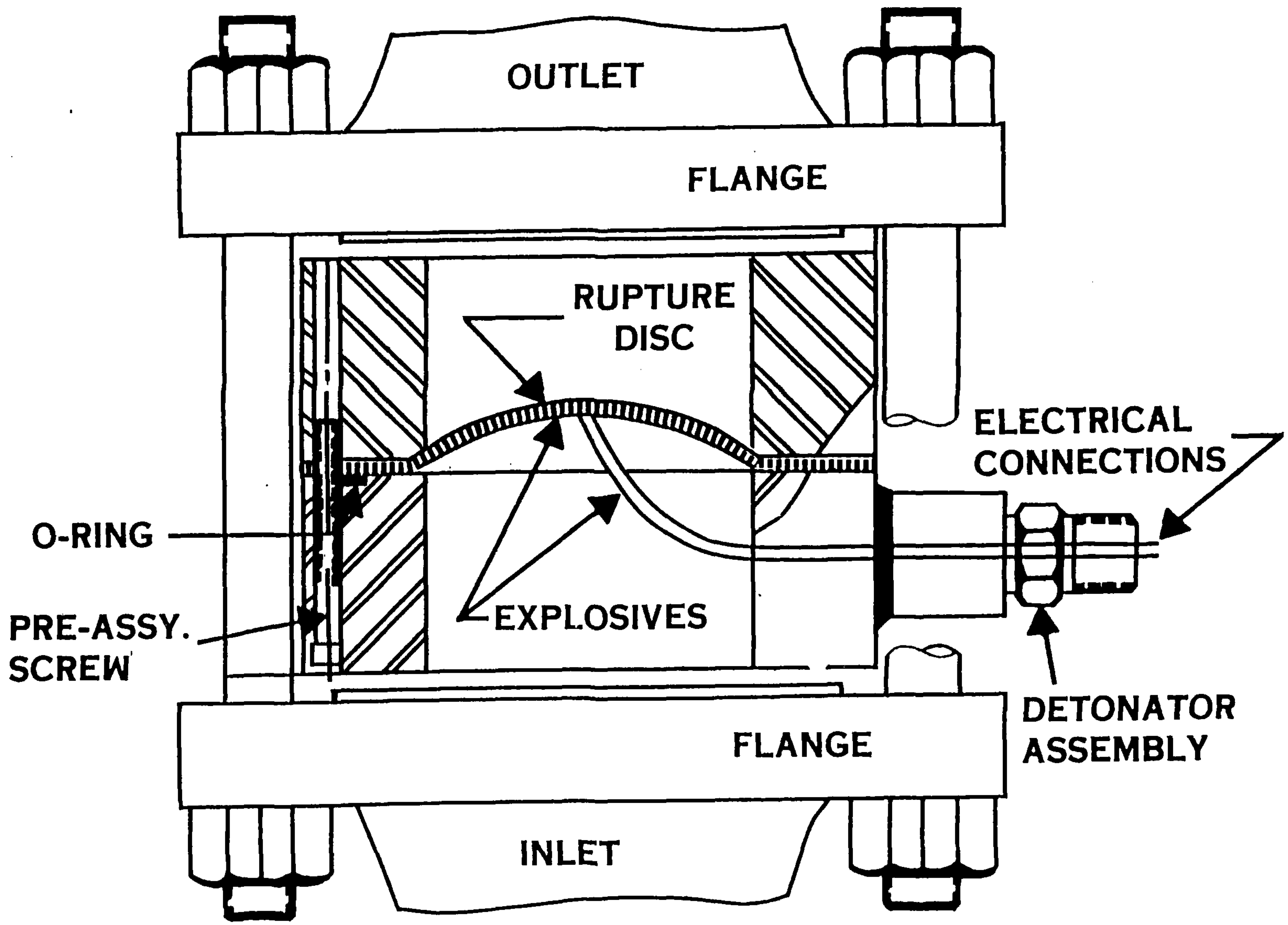


FIGURE 13

EXPLOSIVE RUPTURE DISC

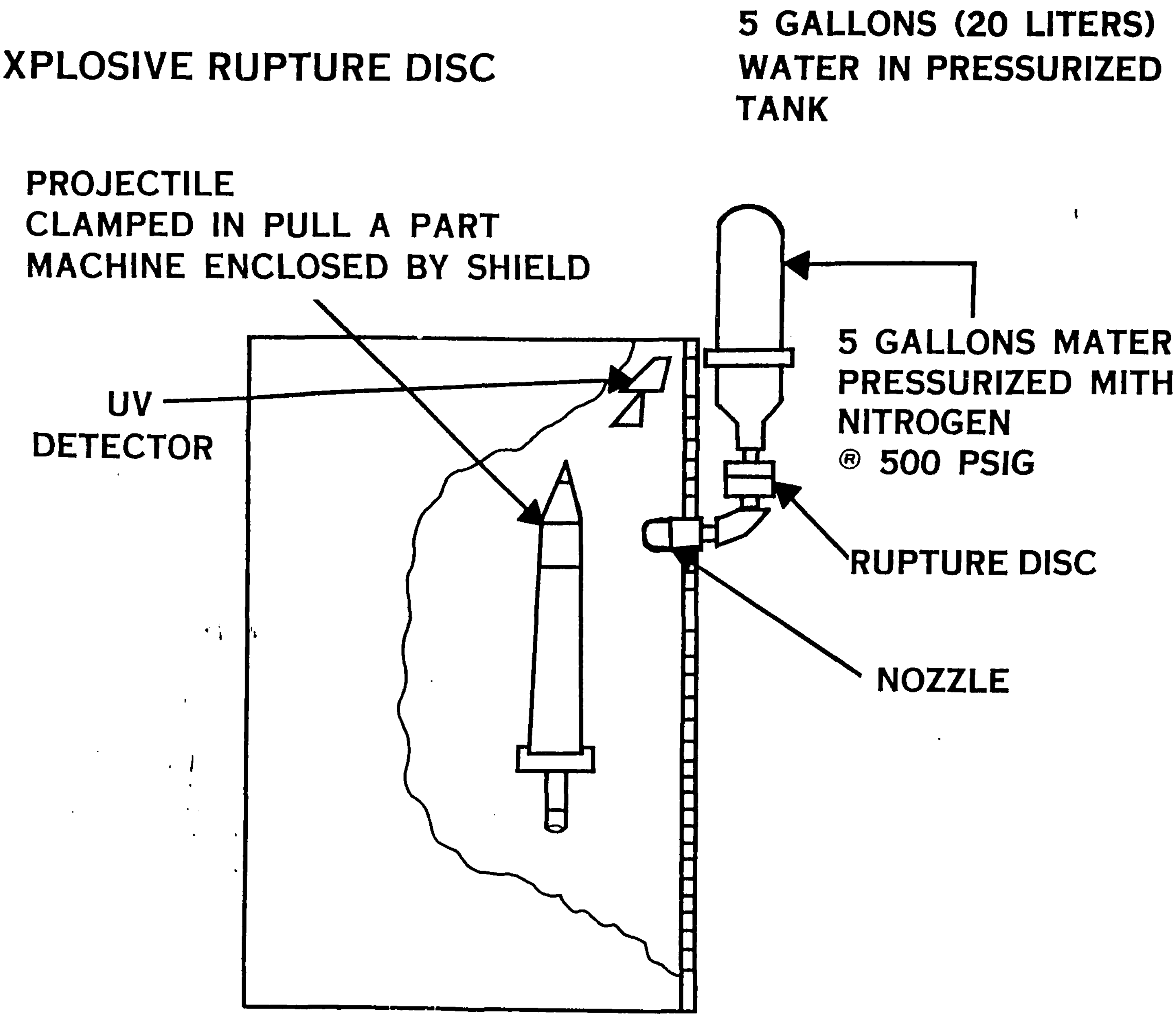


FIGURE 14

DELUGE
SYSTEM RESPONSE TIME

T0 - IGNITION TIME
T1 - SENSING THRESHOLD
T2 - SENSOR RESPONSE TIME
T3 - CONTROLLER RESPONSE TIME
T4 - VALVE OPENING TIME
T5 - FIRST WATER AT NOZZLE TIME
T6 - FIRST WATER ON TARGET TIME
T7 - FULL WATER ON TARGET TIME
T8 - EXTINGUISHMENT TIME

FIGURE 15

DIGITAL TIMER

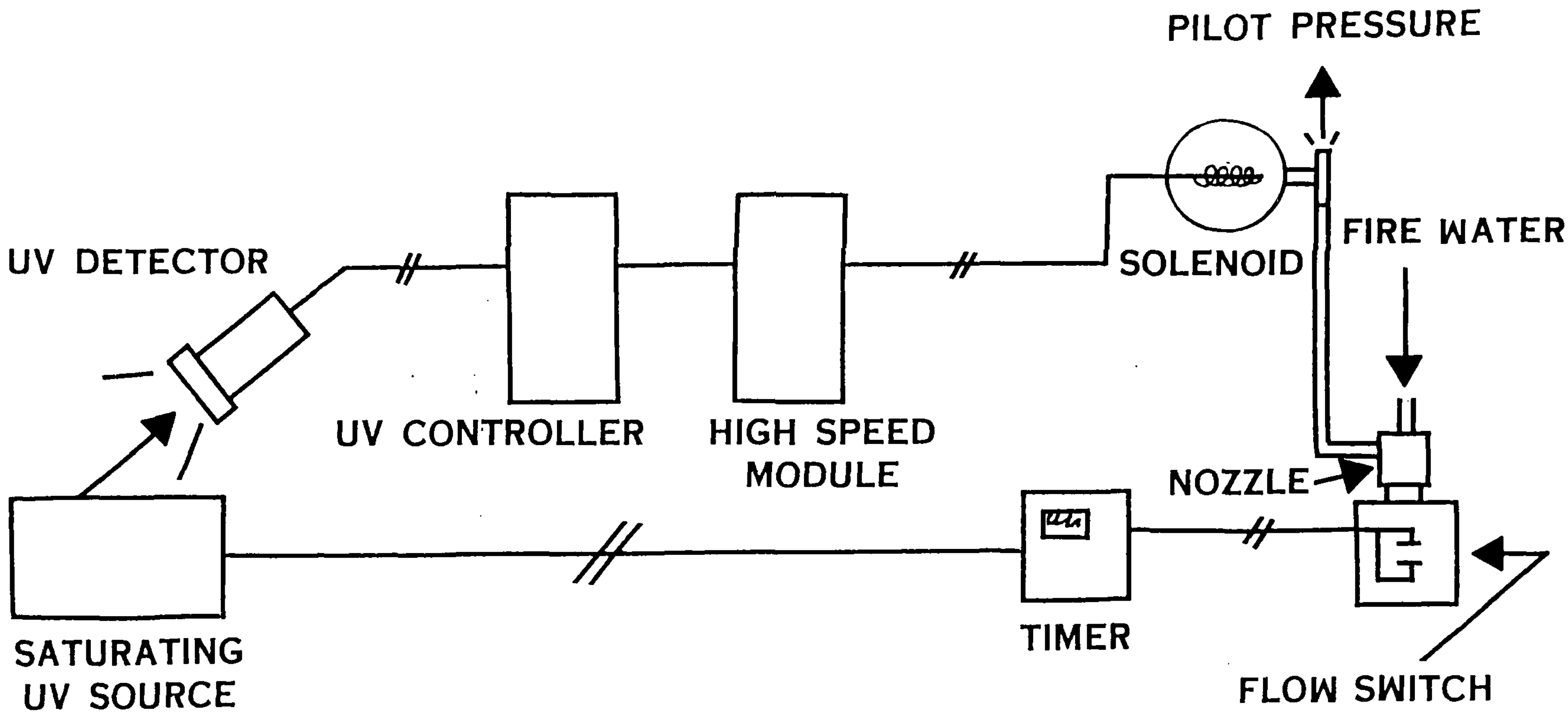


FIGURE 16

HIGH SPEED VIDEO SYSTEM

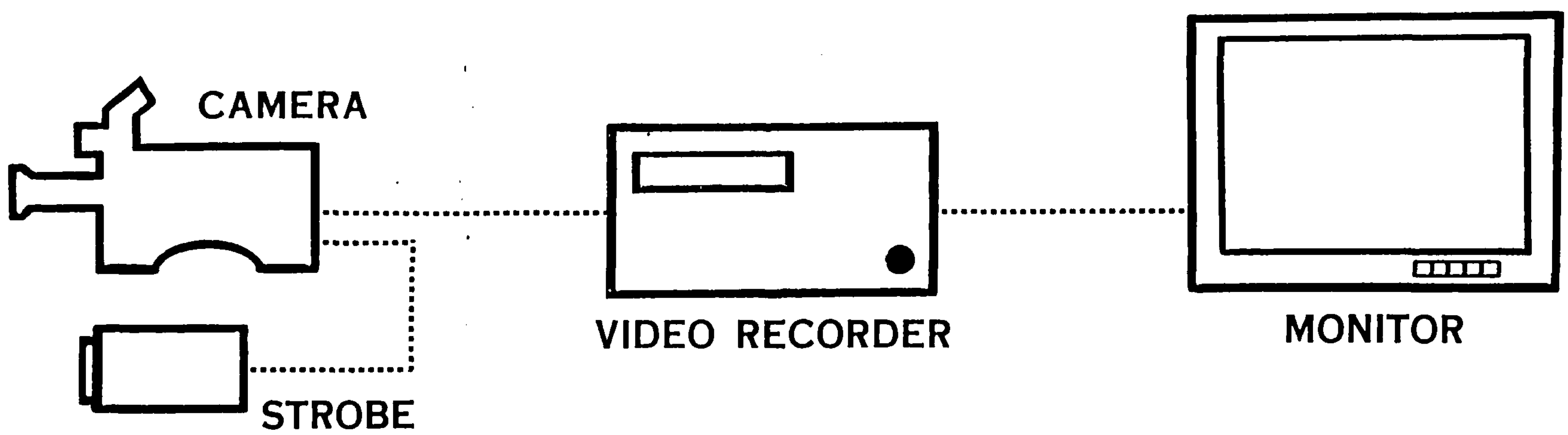


FIGURE 17

AMCR 385-100 DELUGE SYSTEM RESPONSE TIME

— 100 MS FOR 500 GPM OR LESS*

— 200 MS FOR SYSTEMS OVER 500 GPM*

*500 GPM - 1900 LITERS PER MIN

FIGURE 18

APPENDIX A

TECHNICAL REPORTS ON DELUGE SYSTEMS

1. Design of a Deluge System to Extinguish Lead Azide Fires, No. AD-E400 204, Aug 78, approved for public release (APR).

2. Evaluation of Pyrotechnic Fire Suppression System for Six Pyrotechnic Compositions, No. AD-E401 306, Mar 85, APR.

3. Engineering Guide for Fire Protection and Detection Systems at Army Ammunition Plants, Vol I (Selection and design), No. AD-E400 531, Dec 80, APR.

4. Engineering Guide for Fire Protection and Detection Systems at Army Ammunition Plants, Vol II (Testing & Inspection), No. AD-E400 874, Dec 82, Distribution limited to U.S. Government Agencies only - contains proprietary information.

5. On-site Survey and Analysis of Pyrotechnic Mixer Bays, No. AD-E401 141, Feb 84, APR.

6. Feasibility Study to Develop a Water Deluge System for Conveyor Lines Transporting High Explosives, Tech Rpt No. 4889, Aug 75, APR.

7. Development of a Water Deluge System to Extinguish M-1 Propellant Fires, No. AD-E400 217, Sep 78, APR.

8. Design of a Water Deluge System to Extinguish M-1 Propellant Fires in Closed Conveyors, No. AD-E400 216, Sep 78, APR.

9. Fire Suppression System Safety Evaluation, No. AD-E401 083, Dec 83, APR.

10. Dynamic Model of Water Deluge System for Propellant Fires, No. AD-E400 315, May 79, APR.

11. Deluge Systems in Army Ammunition Plants, prepared by Science Applications, Inc., for the U.S. Army Munitions Production Base Modernization Agency, 30 Jun 81.

12. Minutes of the Rapid Action Fire Protection System Seminar, U.S. Army Armament, Munitions and Chemical Command, 23-24 Oct 84.

13. Water Deluge Fire Protection System for Conveyor Lines Transporting High Explosives, No. AD-E400 034, Dec 77, APR.

14. Evaluation of an Improved Fire Suppression System for Pyrotechnic Mixes, No. AD-E401 569, Sep 86, Distribution limited to U.S. Goverment Agencies only.

15. Analysis of Mixer Bay Designs for Pyrotechnic Operations, No. AD-E401 602, Nov 86, APR.

16. Calculating Sprinkler Actuation Time in Compartments, Center for Fire Research, National Bureau of Standards, Mar 84.

17. Guidelines for a Thermochemical Kinetics Computer Program, Los Alamos National Laboratory, LA-10361-MS, May 85.

18. Mathematical and Numerical Methods Used in Thermal Hazards Evaluation, Naval Weapons Center China Lake, NWC TP 6510, Dec 86.

19. Technical Report on the Testing of Ultraviolet Actuated Deluge Systems Utilizing Solid State Controllers and Detonator-Actuated Valves to Extinguish Black Powder Fires, Day and Zimmerman, Lone Star Division, Nov 86.

20. Hazel - "A Computerized Approach to System Safety," Ken Proper, U.S. Army Defense Ammunition Center and School, Equipment Div, Aug 86.

Most of these reports can be ordered from the Defense Technical Information Center, Cameron Station, Alexandria, VA 22314. Their telephone number is AV 284-7633.

APPENDIX B

REFERENCES

1. AMC Safety Manual, AMCR 385-100, 1 Aug 85.

2. DOD Ammunition and Explosives Safety Standards, DOD 6055.9-STD, Jul 84.

3. Maintenance of Fire Protection Systems, TM 5-695 (Army)/FAC MO-117 (Navy)/ AFM 91-37 (Air Force), Oct 81 with Change No. 1.

4. Military Handbook - Fire Protection for Facilities Engineering, Design, and Construction, MIL-HDBK-1008, 30 Apr 85.

5. National Fire Codes, National Fire Protection Association.

APPENDIX C

PORTABLE ULTRA HIGH SPEED DELUGE SYSTEM

The need for a "portable" deluge system has been identified U.S. Army Armament, Munitions, and Chemical Command Safety Office.

a. Army ammunition plants and DESCOM depots perform depot-type operations (maintenance, renovation, and demil) but have only a limited number of maintenance facilities equipped with permanently installed deluge systems. This limits operations involving exposed propellant and pyrotechnics to those bays equipped with deluge systems. Depot-type operations are short run operations, usually lasting less than a week, with each job requiring a different equipment setup. Permanently installed deluge systems are: costly (up to $200,000 per building); must be programed into project funding cycle; require 4 to 6 months to install; require extensive modification for many of the jobs; and there only a few permanently installed systems in ammunition maintenance facilities. This greatly reduces the commanders' flexibility in planning, scheduling, and executing depot-type operations.

b. A recent survey of a major Army Command's ammunition maintenance and surveillance operations was made. Many of the operations involved exposed energetic material and are performed in facilities without deluge systems or water supply.

c. The AMCCOM Safety Office has developed the concept of the portable deluge system. The portable ultra high speed deluge system is a self-contained fire detection and suppression system capable of delivering water to the nozzles within 100 milliseconds from time of detection. It will protect an area approximately 10 feet by 10 feet (3 meters by 3 meters). Detection would be accomplished by ultraviolet detectors coupled with an electronic deluge controller. Upon receiving a signal from the controller, the solenoid-operated deluge valve would open permitting water to flow. Water would be delivered from a pressurized tank. Additional water could be provided via a connection to the building water supply, if available. Electrical components would be suitable for use with exposed explosives (Class II). Electricity for the system could be supplied by commercial power, generator, or battery. To protect a wide range of operations, the detectors and nozzles are adjustable. The system would be mounted on a dolly or skid and be transportable.

d. Advantages:

(1) Provides improved protection for ammunition maintenance, renovation, and surveillance operations by means of a system that can be arranged to protect the hazards presented by a variety of operations and can be moved from location to location.

(2) Provides a substantial cost savings by reducing the need for permanently installed deluge systems in ammunition maintenance, renovation, and surveillance operations. Permanent systems can cost up to $200,000 per building while portable systems would cost about $30,000 or less. Only one or two systems per maintenance building would be required. Additional costs would also be saved when permanent systems do not have to be modified to meet job requirements.

(3) Provides process fire protection for facilities without any permanent water supply.

(4) Provides a system that can be quickly and easily moved to the location it is needed.

(5) Provides improved management flexibility for the scheduling and execution of maintenance, renovation, demil, and surveillance operations requiring deluge protection.

e. A commercial company has developed a working prototype of a portable ultra high speed deluge system. They have successfully tested their prototype with small quantities of black powder and propellant. The Ammunition Equipment Directorate (AED), Tooele Army Depot has developed and successfully tested a very small self-contained deluge system for two pieces of Ammunition Peculiar Equipment. Based on this, the concept of the portable ultra high speed deluge system is valid.

f. Two versions of the portable deluge system need to be developed. Both systems would be mounted on a skid or dolly and have deluge nozzles, ultraviolet detectors, and controllers. One system would have two pressurized water tanks and be completely self-contained. It would be used in facilities without a permanent water supply. The other system would have a single pressurized tank and also be connected to the building water supply system. It would be used in facilities that have a permanent water supply.

g. A prototype portable ultra high speed deluge system is currently being tested.

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